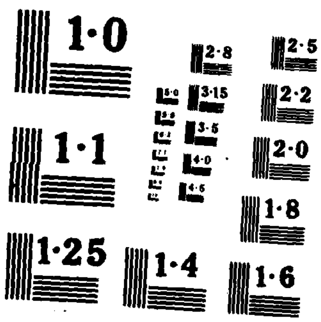
AD A161 158 SCCE REHOSTING FEASIBILITY ASSESSMENT(U) COMPUTER SCIENCES CORP FALLS CHURCH VA SYSTEMS DIV S DRESSLER ET AL. 31 OCT 85 DCA100-81-C-0044 1/2

UNCLASSIFIED F/G 17/2 NL


1·0
2·8
2·5
3·15
2·2
3·5
1·1
4·0
2·0
4·5
1·8
1·25
1·4
1·6

AD-A161 158

(2)

# SCCE REHOSTING FEASIBILITY ASSESSMENT

Prepared for

The Defense Communications Engineering Center
Reston, Virginia 22090

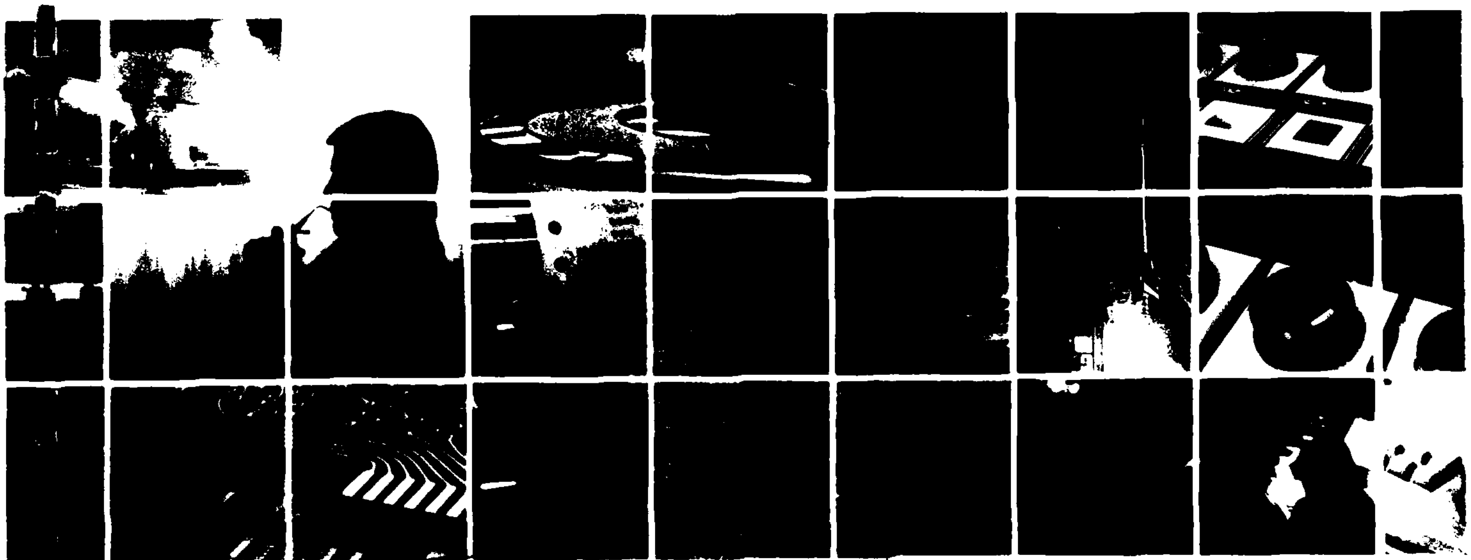
DTIC
ELECTE
NOV 15 1985
S D
E

DTIC FILE COPY

Under

Contract No. DCA100-81-C-0044
Task Order No. 85-2-B

OCTOBER 1985



This document has been approved for public release and sale; its distribution is unlimited.

85 11 14 086

CSC

COMPUTER SCIENCES CORPORATION
SYSTEMS DIVISION

# SCCE REHOSTING FEASIBILITY ASSESSMENT

Prepared for

The Defense Communications Engineering Center
Reston, Virginia 22090

Under

Contract No. DCA100-81-C-0044
Task Order No. 85-2-B

OCTOBER 1985





CSC
COMPUTER SCIENCES CORPORATION
SYSTEMS DIVISION

# SCCE REHOSTING
# FEASIBILITY ASSESSMENT

Prepared for

The Defense Communications Engineering Center
Reston, Virginia

Under

Contract No. DCA100-81-C-0044
Task Order No. 85-2-B

Prepared by

Computer Sciences Corporation
6565 Arlington Boulevard
Falls Church, Virginia 22046

October 1985

TABLE OF CONTENTS

## LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES

## LIST OF TABLES

## EXECUTIVE SUMMARY

### E.1 BACKGROUND

The Office of the Secretary of Defense (OSD) has directed that a Survivable DSCS Control System (SDCS), including an SCCE, be developed. The SDCS is required to provide a survivable, autonomous minimal DSCS III network control capability. The SDCS will be a transportable configuration that meets stringent environmental requirements. The SCCE's MODCOMP Classic II/75 computer will not meet the environmental requirements of the SDCS. Consequently, it will be necessary to rehost the SCCE to a militarized computer. Within the DSCSOC, several DOCS subsystems use DEC VAX computers. These subsystems will be incorporated into the SDCS, and will require rehosting to a militarized computer. Applications on the DEC VAX computers will run on the Norden Systems Inc. line of MIL VAX computers with minimal software conversion. Thus, these subsystems will likely be rehosted to MIL VAX computers.

Consequently, in order to improve the commonality of computer equipment and simplify the logistic support of the SDCS, the Norden Systems Incorporated line of militarized VAX computers is a prime candidate for the rehosting of the SCCE in the SDCS.

The rehosting of the SCCE to the Norden MIL VAX computer will require software conversion, as well as the use of appropriate militarized peripheral equipment and interface hardware. Once the software is converted to the MIL VAX computer, it will also be compatible with the commercial DEC VAX family of computers.

Consequently, after the SDCS development has been accomplished, the replacement of the MODCOMP computer in the DSCSOC with a DEC VAX 11/780 will entail only minimal software conversion, and will improve the commonality of the SCCE with the other DEC VAX based subsystems.

## E.2 REQUIREMENTS

In the DSCSOC, the SCCE must concurrently support two active satellites. In addition, it must maintain a data base for a third, standby, satellite, and provide the capability for a rapid switchover from an active satellite to the standby satellite. In the SDCS, the SCCE must support only one active satellite while providing the capability for switchover to a second, standby satellite.

## E.3 STUDY OBJECTIVES

This study has three primary objectives:

a. The analysis of the MODCOMP based SCCE to determine its software and hardware characteristics and to estimate its performance.

b. The assessment of the feasibility, complexity and cost of rehosting the SCCE to a MIL VAX computer in the SDCS.

c. The assessment of the feasibility, complexity and cost of rehosting the SCCE to a DEC VAX computer, after the rehosting to a MIL VAX computer is completed.

In conducting this study, CSC has attempted to provide information and insights that will support a low risk, evolutionary approach to the proposed rehosting efforts.

## E.4 FINDINGS

The major findings are summarized below:

a. The current SCCE uses a MODCOMP Classic II/75 computer, with 2 megabytes (MB) of primary memory and 3 disk units. It adequately supports 2 active satellites with real time and interactive processing.

b. The SCCE software consists of 243K lines of FORTRAN and 64K lines of assembler and other machine-unique code. (refer to Table E-1). The FORTRAN code is easily converted to either the MIL VAX or DEC VAX computers. The assembler code will have to be rewritten.

Table E-1
SCCE Software Summary

| SOFTWARE ELEMENT | FORTRAN LINES OF CODE | ASSEMBLER LINES OF CODE |
|---|---|---|
| Applications | 243,000 | 36,000 |
| System | 0 | 28,000 |
| Total SCCE | 243,000 | 64,000 |

c. Some FORTRAN routines on the MODCOMP have embedded (in-line) assembler code. Neither the MIL VAX nor DEC VAX computers permit the use of embedded assembler. This assembler code will have to be converted into external assembler routines.

d. The SCCE in the SDCS can be hosted on a MIL VAX I computer with 4MB of primary memory and 2 disk units. Militarized equipment is available to support all computer interfaces. The MIL VAX I computer has slightly improved performance over the MODCOMP Classic II/75. The performance and rehosting costs of this system, in support of one satellite, appear in Table E-2 and Table E-3, respectively. Adequate margins exist for all key parameters.

Table E-2. MIL VAX System Performance

| COMPUTER | PROCESSOR UTILIZATION | | | I/O UTILIZATION | |
|---|---|---|---|---|---|
| | Avg | Plybk | Busy Min | Channel (Avg.) | Disk* |
| MODCOMP | .25 | .48 | .33 | N/C | .11/.44 |
| MIL VAX I | .20 | .38 | .27 | .11 | .12/.48 |

*Average/Peak

Conversion costs are estimated in Table E-3

Table E-3. MIL VAX Conversion Costs
(Fully Loaded)

| COST ELEMENT | COST |
|---|---|
| LABOR | $3,785,000 |
| HARDWARE (One Site) | 833,363 |
| TOTAL COST | $4,618,363 |

*Excludes Auxiliary Executive Routines

e. The SCCE in the DSCSOC can be rehosted on a DEC VAX 11/780 computer with 6 MB of primary memory and 3 disk units. Commerical equipment is available to support all computer interfaces. The VAX 11/780 has slightly improved performance over the MODCOMP Classic II/75. The performance and rehosting costs of this system in support of two satellites appear in Table E-4 and Table E-5, respectively.

Table E-4. DEC VAX 11/780 System Performance

| COMPUTER | PROCESSOR UTILIZATION | | | I/O UTILIZATION | |
|---|---|---|---|---|---|
| | Avg | Plybk | Busy Min | Channel (Avg.) | Disk* |
| MODCOMP | .50 | .72 | .66 | N/C | .22/.55 |
| VAX 11/780 | .38 | .54 | .50 | .45 | .24/.60 |

*Average/Peak

Estimated conversion costs are presented in Table E-5.

Table E-5. DEC VAX 11/780 Conversion Costs (Fully Loaded)

| COST ELEMENT | COST |
|---|---|
| LABOR | $ 736,000 |
| HARDWARE (One Site) | 380,829 |
| TOTAL COST | $1,116,829 |

f. The DEC VAX 11/780 configuration, under peak conditions appears to have inadequate margin for disk utilization. Particular attention should be paid to verifying this analytical result and/or to evaluating possible work-around approaches (e.g., minor software redesign or spreading of the satellite files over two disks). With the satellite files spread over two disks, peak utilization will drop to 0.50, providing a comfortable margin of safety. This low risk approach reduces disk utilization, but reduces the system's ability to overcome certain types of equipment failure.

## E.5 RECOMMENDATIONS

As a means of reducing the programmatic risk associated with the rehosting of the SCCE, CSC makes the following recommendations:

a. The existing MODCOMP system at GE should be used as much as possible as a test bed. It can be used to verify CSC's calculated system performance under peak loading conditions, particularly to evalute actual system margins.

b. The embedded assembler code on the MODCOMP should be replaced with externally called routines. This will permit the evaluation of its impact on performance.

c. Disk activity under peak loads should be measured using the MODCOMP system. If sufficient margins are not present, then work-around approaches should be evaluated.

## E.6 CONCLUSIONS

The SCCE can be rehosted to a Norden Systems Inc. militarized MIL VAX I computer system to satisfy the requirements for satellite control in the SDCS. Software conversion, which will be a large part of the rehosting effort, can be accomplished with minimal risk.

Once the rehosting to the MIL VAX I is completed, the subsequent rehosting to the DEC VAX 11/780 is a low risk effort. Applications software from the MIL VAX I system will be directly usable without conversion; some systems software will have to be rewritten.

## 1. INTRODUCTION AND SCOPE

This report presents the results of a study of the feasibility of redesigning the DSCS Satellite Configuration Control Element (SCCE) so that it can be fielded in a transportable configuration. The principal area of redesign involves the SCCE's commercial grade MODCOMP computer which is not suitable for a mobile environment.

This analysis has been performed by Computer Sciences Corporation under contract DCA100-81-C-0044, Task Order 85-2-B for the Satellite Systems Development Division (Code R420) of the Defense Communications Engineering Center. The study has taken approximately six calendar months.

The Office of the Secretary of Defense (OSD) has directed that a Survivable DSCS Control System (SDCS) be developed by the Army (USASATCOMA) with first article delivery planned for FY 1988. In order to meet this extremely tight schedule, it is planned to redesign and repackage existing network and satellite control subsystems from the fixed DSCS Operations Center (DSCSOC) into the required mobile configuration. The highest risk area that has currently been identified in the repackaging strategy is a proposed replacement of the large and fragile Modular Computers, Inc. (MODCOMP) fixed-plant computer system used in the SCCE with a ruggedized, militarized replacement.

Included in the DSCSOC is the MODCOMP based SCCE, and several subsystems using Digital Equipment Corporation (DEC) VAX computers (refer to Figure 1-1). Consequently, in order to improve the commonality of computer equipment and thus simplify logistic support of the SDCS, a common militarized computer is required. Although several manufacturers offer candidate ruggedized systems, the line of militarized VAX computers from Norden Systems Incorporated appears to offer the best choice for

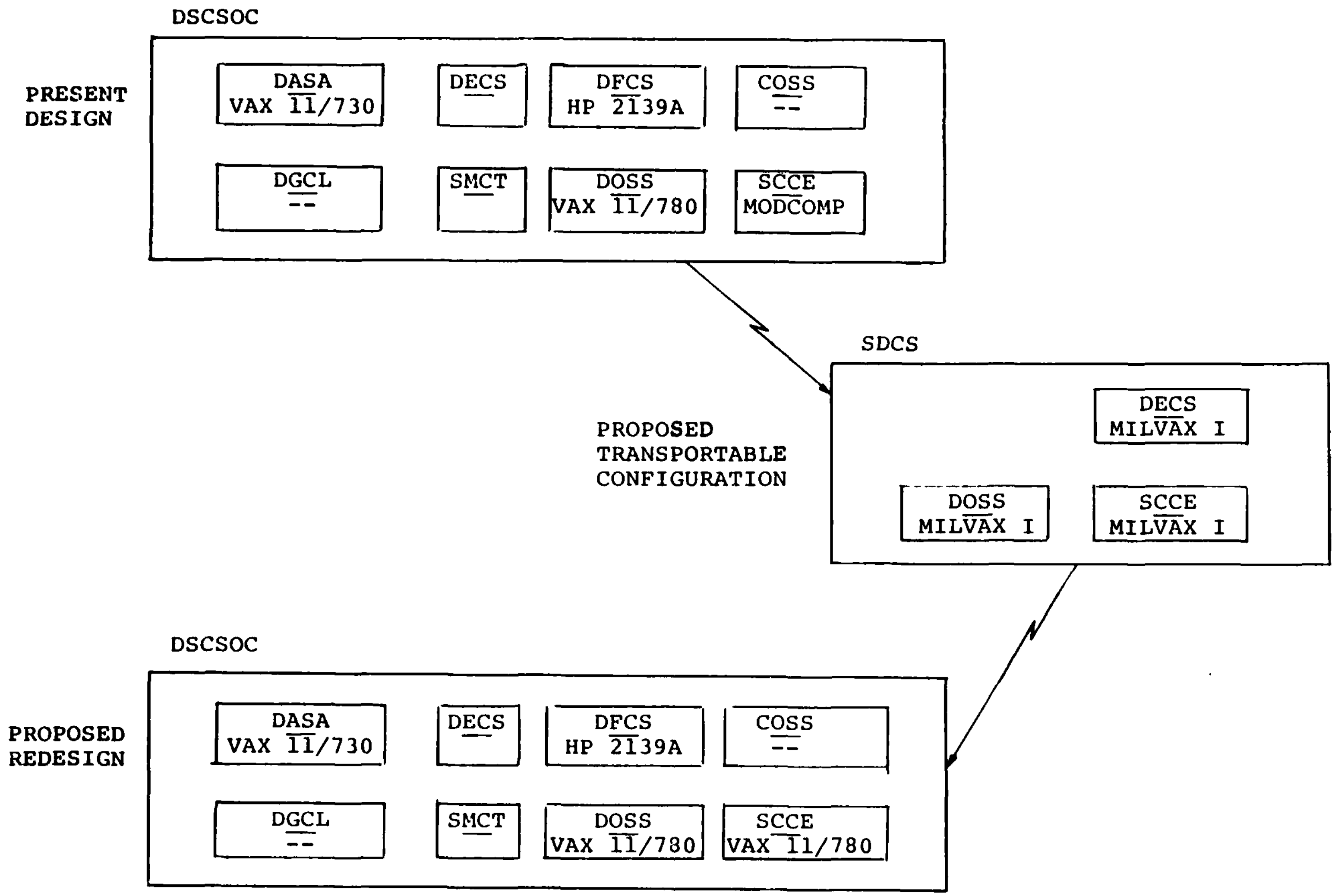



Figure 1-1. Evolutionary SCCE Rehosting

the target computer. These MIL VAX computers are software compatible with the DEC VAX equipment and use the DEC VMS operating system and other DEC software. Consequently, this study has used the MIL VAX computers as the target machine.

The rehosting of the SCCE from a MODCOMP computer to a MIL VAX computer will require changes in both hardware and software. Hardware changes will be necessitated by differences in computer characteristics and by the more stringent environment of the mobile configuration. Software changes will be required due to some differences in the FORTRAN language processors and different assemblers as well as job control statements. This will include modifications to MODCOMP-based FORTRAN application software in order to make it compatible with the MIL VAX FORTRAN and the rewriting of assembly language routines. These changes in the SCCE hardware and software will make the resulting system compatible with the DEC VAX family of computers. Thus, as a secondary objective, CSC has analyzed the feasibility of replacing the MODCOMP in the fixed environment of the DSCSOC with a DEC VAX computer. This would improve the commonality of equipment and software as well as logistic support of the DSCSOC. In following the programmatic path from the present MODCOMP implementation to a MIL VAX system in the SDCS, and thence to a DEC VAX system in the DSCSOC, USASATCOMA has a low risk, evolutionary approach to meeting new requirements and improving the supportability of the SCCE (Refer to Figure 1-1).

In conducting this study, CSC has relied heavily on the formal documentation of the SCCE. The documentation has included specifications, interface control documents, source code listings, handbooks, etc. A complete list of such documents appears in Table 1-1. Because of their availability, CSC has primarily used documents describing the Engineering Development Model or the Interim Production Model.

In analyzing the potential rehosting of the SCCE to a MIL VAX computer, certain critical parameters must be considered. These are primarily related to the adequacy of computer resources, viz, primary memory, secondary memory (disk), and to the computer's performance, viz, processor rate, I/O bus transfer rate. However, the most important parameter is the ability of the rehosted system to meet the performance requirements of the SCCE. These requirements are to perform the functionality of the SCCE within the necessary response times. In addition, we are concerned with the portability of the applications software, and the ability of the target system to provide a "clean", functionally correct interface with the non-computer portion of the system.

Table 1-1. SCCE Descriptive Documentation

SCCE Specifications/Interface Control Documents (G.E.)

| Document Number | Title |
|---|---|
| SVS-9644-II-A | CPCI Specification, Part II Computer Program Development Specification TCP, Source Listings |
| SVS-9788 | SAT/PSCCE Interface Control Document |
| SVS-10710-I | Prime Item Product Development Specification (IPM SCCE) |
| SVS-10710-II | Prime Item Product Fabrication Specification (IPM SCCE) |
| SVS-10712 | Hardwre/Software Interface Control Document (IPM) |
| SVS-10738-I | Computer Program Development Specification TCP (IPM SCCE) |
| SVS-10738-II | Computer Program Product Specification TCP (IPM SCCE) |
| SVS-10739-I | Computer Program Development Specification CCP (IPM SCCE) |
| SVS-10739-II | Computer Program Product Specification CCP (IPM SCCE) |
| SVS-10766 | DOSS/PSCCE Interface Control Document |
| SVS-10767 | RFIS/PSCCE Interface Control Document |
| SVS-10770-I | CD/CPS Development Specification (PSCCE) |
| SVS-10771-I | TCS Development Specification (PSCCE) |
| SVS-10774-I | ETI/CCTS Development Specification (PSCCE) |

Table 1-1. SCCE Descriptive Documentation (Cont'd)

<u>SCCE Specifications/Interface Control Documents (G.E.) (Cont'd)</u>

| Document Number | Title |
|---|---|
| SCA-2299 | RFIS/IPM SCCE Interface Control Document |
| SCF-ICD-115 | SCF/SCCE Interface Control Document |
| SUM-10738 | Telemetry and Command Program User Manual |
| SUM-10739 | Communication Configuration Program User Manual |
| TR-SCCE-401 | Test Report for the Hardware Software Integration of the IPM of the SCCE #4 |

Table 1-1. SCCE Descriptive Documentation (Cont'd)

MODCOMP Manuals

| Document Number | Title |
|---|---|
| 210-60050-008 | Reference Manual MAX II/III/IV Systems Processors Assemblers |
| 210-610501-000 | Reference Manual MAX IV Input/Output Model 8240 |
| 210-804002-E01 | Language Reference Manual MAX IV FORTRAN IV |
| 210-804003-B01 | Programmer's Reference Manual MAX III/IV Link Loader |
| 211-834001-C02 | Programmer's Reference Manual MAX IV NASA Extended FORTRAN 78 |
| 213-804005-H01 | System Guide MAX IV Basic I/O System |
| 213-804007-H02 | System Guide MAX IV Data Storage Device Handlers |
| 220-610400-001 | MAX IV Library Concepts and Characteristics |
| 224-321001-001 | Theory of Operation Classic II Input/Output Processor |
| 224-404009-002 | Theory of Operation Classic Moving-Head Disk Controller Model 4176A |
| 224-408005-001 | Theory of Operation Classic Series Controller DMP Line Printer |
| 224-410001-001 | Theory of Operation Classic Series Console Controller |
| 224-421002-000 | Theory of Operation Communications Interfaces |
| 224-421005-002 | Theory of Operation Classic Series Asynchronous Terminal Controller |

Table 1-1. SCCE Descriptive Documentation (Cont'd)

MODCOMP Manuals

| Document Number | Title |
|---|---|
| 224-426001-001 | Theory of Operation Quad Channel Interface Controller (4804) (QCIC) |
| 224-427001-001 | Theory of Operation Classic Series Parallel Interface Controller |
| 224-722001-001 | Theory of Operation Classic II Central Processor Model CLII/75 |
| 225-200085-001 | Technical Manual Electrostatic Printer/Plotter (Models 4216 and 4217) |
| 225-200125-001 | Data Terminal/Computer Link, Model 4805-1/Model 4802, Theory of Operation |
| 226-722001-004 | Computer Reference Manual Classic Central Processor CLII/75 |

Other Documents

Norden Systems Inc. MIL VAX I Manuals

Digital Equipment Corporation VAX 11/780 Manuals

## 2. BACKGROUND

### 2.1 DSCSOC SCCE Capability

#### 2.1.1 General

The DSCSOC-based SCCE is a ground based satellite command and telemetry processing system consisting of equipment and computer programs collocated and interfacing with a DSCS Earth Terminal. The SCCE provides the following capabilities for operational command and control of two active and one standby DSCS satellites:

a. Generate and transmit commands and command sequences.

b. Acquire, process, record and display telemetry data.

c. Interface with DOSS

d. Interface with the Air Force Satellite Control Facility (AFSCF) for:

(1) Command backup

(2) Generation of non-payload related commands

(3) Anomaly resolution

(4) Orbital parameter support to the SCCE

### 2.2 GE/MODCOMP Implementation

#### 2.2.1 Description

To accomplish the above functions, the SCCE is, as designed by the General Electric Corporation (G.E.), comprised of the following major subsystems (refer to Figure 2-1):

a. Control and Display/Computer and Peripheral Subsystem (CD/CPS)

b. Telemetry and Command Subsystem (TCS)

c. Earth Terminal Interface/Checkout Calibration and Test Subsystem (ETI/CCTS)

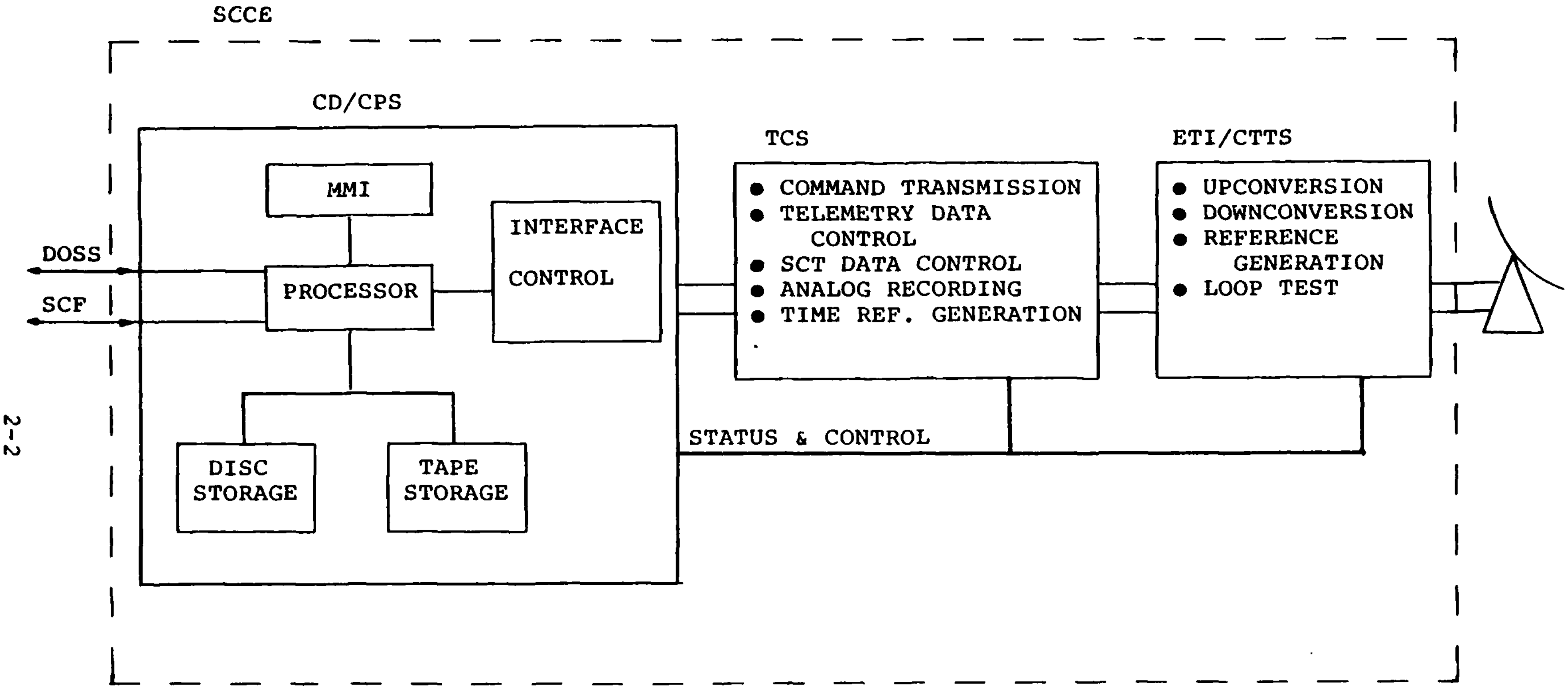



Figure 2-1. SCCE Functional Block Diagram

d. Software Subsystem consisting of the following major programs:

   (1) Telemetry and Command Program

   (2) Communications Configuration Program

2.2.2 Control and Display/Computer and Peripheral Subsystem (CD/CPS)

The Control and Display/Computer and Peripheral Subsystem consists of the computer equipment, and associated storage and terminal devices (man-machine interface) required to support the functions described above. In addition to providing the principal processing capability of the SCCE, the CD/CPS provides real time control of functions within the Telemetry and Command Subsystem and Earth Terminal Interface/Checkout Calibration and Test Subsystem, and provides control and status monitoring of those subsystems.

The CD/CPS consists of the following equipment:

a. MODCOMP Classic II/75 Computer - A 16-bit machine with 2 megabytes of primary storage.

b. Three moving head disks (MHD) - Each MHD is capable of storing 67 megabytes, and has its own controller to provide data base redundancy in the event of a malfunction.

c. Two magnetic tape units (MTU) - Each MTU is a 9 track, 75 inches per second, 800/1600 bits per inch - NRZI/Phase Encoded unit with a single controller.

d. Parallel and serial interface devices.

Locations are provided for SCCE operation from a Payload Controller's position and/or from a Maintenance and Analysis position. These positions include the following computer terminal equipment:

a. Printer/Plotter - A Versatec V80 plotter wth 200 data per inch resolution, 1.2 inches per second paper speed and a dot matrix printing speed of 1,000 lines per minute. A separate controller provides the capability for plotting, printing, and hard copy display from the Graphic Display terminal.

b. Alpha-numeric CRT terminals.

c. Graphics Display terminal - A Tektronix 4014-1 provides 1920 characters or a 512 by 512 point capability for vector and graph presentation.

d. Program Function Keyboard

e. Line Printer.

### 2.2.3 Telemetry and Command Subsystem (TCS)

The TCS provides the following functions:

a. Control of uplink command flow.

b. Control up downlink telemetry flow.

c. Control of Single Channel Transponder (SCT) telemetry information flow.

d. Generation of IRIG B time for data recording.

e. Analog recording of telemetry data.

f. Strip chart recording of telemetry data.

### 2.2.4 Earth Terminal Interface Checkout Calibration and Test Subsystem (ETI/CCTS)

The ETI/CCTS provides the following functions:

a. DSCS Earth Terminal RF interface.

b. Command and telemetry interface with the TCS.

c. Provisions for command and telemetry self check.

d. Calibration and self check.

## 2.3 SDCS Requirements

The SDCS is required to provide a survivable autonomous minimal network control capability for the operation of DSCS III networks. During the period of SDCS operation, it is assumed that other fixed DSCS operations facilities (e.g., DSCSOCs, AFSCF) are no longer available. Hence the SDCS must provide autonomous network control to the extent possible.

The SDCS must provide the capability to perform the following three major control functions:

a. Network Control

b. Payload Control

c. Satellite Control

Implementation of Network Control will be provided by the DOSS System and the DECS System. Payload control, i.e., the control of the DSCS III satellite communication payload, will be provided by the SCCE. In addition, the SCCE will provide control of the satellite platform.

### SDCS Limitations

The SDCS will operate with a single terminal. This will limit the SDCS to the support of a single DSCS satellite. This is in contrast to the usual operation of a DSCSOC which concurrently supports two DSCS satellites (see Table 2-1). The SDCS will be

in a trailer with considerably less space than is found in the DSCSOC. Consequently, fewer operations personnel will be present in the SDCS, resulting in less terminal and peripheral equipment, some of which is shared among the SDCS systems. Because the SDCS configuration is transportable, the SDCS environmental requirements are more stringent (e.g., shock, vibration, dust) than that of a DSCSOC. Consequently, militarized equipment will be used.

Table 2-1. Functional Requirements/Capability

| DSCSOC | SDCS |
| --- | --- |
| GENERATE AND TRANSMIT COMMANDS | GENERATE & TRANSMIT COMMANDS |
| ACQUIRE & PROCESS TELEMETRY DATA FOR 2 ACTIVE SATELLITES<br>PROVIDE DATABASE FOR 3rd SATELLITE | ACQUIRE & PROCESS TELEMETRY DATA FOR 1 ACTIVE SATELLITE<br>PROVIDE DATABASE FOR 2nd SATELLITE |
| INTERFACE WITH DOSS | INTERFACE WITH DOSS |
| INTERFACE WITH SCF<br>o COMMAND BACKUP<br>o NON-PAYLOAD COMMAND GENERATION<br>o ANOMALY RESOLUTION<br>o ORBITAL PARAMETER INPUT | PROVIDE AUTONOMOUS<br>o NON-PAYLOAD COMMAND GENERATION<br>o ANOMALY RESOLUTION<br>o ORBIT DETERMINATION |

## 2.4 SDCS/SCCE MIL VAX DESIGN

The SDCS/SCCE will include the previously described ETI/CCTS and the TCS, each suitably modified to accommodate the MIL VAX computer interface. In addition, these subsystems will contain only that equipment needed for the support of a single satellite.

The Control Display/Computer and Peripheral Subsystem (CD/CPS) will be based on a MIL VAX I computer supported by appropriate terminals and peripherals. The CD/CPS will support a single DSCS III satellite and will maintain a data base for a second (backup) DSCS III satellite. Switchover from one active satellite to the second (backup) satellite will be accomplished in less than 15 minutes. This time is established by the time required to re-orient the SDCS's single antenna to the backup satellite and to recognize the satellite's IF signals. Because of the reduced floor space in the SDCS, the CD/CPS will be supported by ruggedized rack mounted disk units.

The Man-Machine Interface (MMI) will consist of a Maintenance and Analysis Operator's Position located in the SDCS van and a Payload Controller's Position located outside the van and connected by a fiber optic interface for the purpose of this study. This remote interface has been considered as not affecting the processing which supports the terminal devices listed in Table 2-2.

Table 2-2. SDCS/SCCE Terminal/Peripheral Devices

| Type | Payload Controller | Maint/ Analysis | Total |
|---|---|---|---|
| Alphanumeric/Graphics CRT[1] | 2 | 2 | 4 |
| Printer/Plotter | 1 | 1 | 2 |
| Strip Chart Recorder | | 1 | 1 |
| Disk Drive | | | 2 |
| Magnetic Tape Unit | | | 1[2] |

[1] Includes programmable function keyboard capability

[2] Shared with DECS

It has been assumed that all SCCE FORTRAN programs will be readily converted to run on the MIL VAX computer, and that all assembler programs will be rewritten for the MIL VAX. In the rehosting of this software, CSC has assumed that the number of lines of code obtained will not differ significantly from the lines of code in the MODCOMP implementation.

## 2.5 DSCSOC Requirements

If the SCCE software is rehosted to a MIL VAX, then it can be assumed that the MIL VAX version of the software will be capable of being run on a DEC VAX computer with minimal conversion effort. Thus the creation of a DEC VAX based SCCE for operation in the DSCSOC will require hardware changes to incorporate a commercial DEC VAX processor, peripheral devices, terminal equipment and interface converters for the TCS and ETIS equipment.

The functional requirements of a DEC VAX based SCCE, operating in a DSCSOC, will be the same as the functional requirements for the MODCOMP based SCCE. The DEC VAX system in the DSCSOC will be required to concurrently support two DSCS III satellites while maintaining a data base for a third satellite, with provision for rapid switchover to the standby satellite.

## 3.0 OBJECTIVE OF THE STUDY

### 3.1 SDCS Design

The primary objective of the study is to assess the rehosting of the SCCE from the DSCSOC MODCOMP implementation to the SDCS MIL VAX implementation. The assessment is to include hardware and software conversion plus both quantitative measures, e.g., cost, and qualitative aspects, e.g., "difficulty" of specific code conversion.

The change from the MODCOMP computer to the MIL VAX (or any other computer) introduces corresponding changes in the hardware/software interfaces (to the Telemetry and Command Subsystem and to the Earth Terminal Interface Subsystems). These changes are due to difference in computer architecture, computer word size, instruction, etc. The basic issue to be answered by this study is: can the rehosting of the SCCE from the MODCOMP to the MIL VAX be accomplished in a way that permits cost-effective re-use of the applications software and an operationally effective hardware interface?

Implicit in this issue are the following elements:

a. Size of the applications software (lines of code).

b. Processing load of the applications software (number of instructions per second).

c. Primary memory needed to support the applications software (KB).

d. Secondary memory (disk storage) needed to support the file structure (MB).

e. Input/output channel capacity needed to conduct the necessary processing (KB/sec).

f. Availability of computer resources to support the items above.

g. Relative ease (or difficulty) of converting or rewriting the applications software.

It should be pointed out that most of the application software is written in FORTRAN and, therefore, should be easily converted to the MIL VAX environment. However, some of the applications software is written in assembler. This code must be rewritten. System macros must also be rewritten.

In order to accomplish this assessment, CSC has determined the processing load (by analyzing source code), and has estimated storage requirements (both primary memory and disk). Also, CSC has designed a hardware system based on the MIL VAX computer and appropriate ruggedized peripherals. In some aspects, excess capacity (over the original MODCOMP system) has been incorporated to use readily available ruggedized equipment. This achieves some margin of safety in the design at additional cost. CSC has sought to design a "feasible" system for the purpose of identifying the necessary devices, interface adapters, etc. Optimization of cost vs performance has not been done.

In conducting this assessment, CSC has concentrated on the CD/CPS and the interfaces with the TCS and ETI/CTTS. We have assumed that the characteristics of the TCS and ETI/CTTS do not change from the MODCOMP/DSCSOC environment to the MIL VAX SDCS environment.

3.2 DSCSOC Design. A secondary objective of the task is to assess the rehosting of the SCCE from the DSCSOC MODCOMP implementation to a DSCSOC DEC VAX implementation, assuming that the conversion of the software from MODCOMP to MIL VAX has already been achieved. This assessment includes the consideration of hardware

and software conversion. To determine the processor load, CSC has used the loading analysis developed for the SDCS MIL VAX system, suitably modified to account for the concurrent processing of two satellites. CSC has designed a hardware system based on a DEC VAX computer and appropriate peripherals. The design takes advantage of recent cost-performance improvements in computer hardware to include more main memory in the DEC VAX system (6 MB) than is presently in the MODCOMP (2 MB). Add-on memory costs $2K/MB.

This design also assumes that the characteristics of the TCS and ETI/CTTS do not change from the MODCOMP/DSCSOC environment.

# 4.0 MODCOMP SYSTEM

## 4.1 Current GE SCCE System Architecture

Figure 4-1, taken from GE document WPC-2429D-316D (page 8) illustrates the SCCE architecture for a two satellite system. Only the CD/CPS subsystem is of interest to this study in that the study objective is to determine the feasibility of replacing the MODCOMP CLASSIC II/75 computer with a DEC VAX 11/780 (DSCSOC) and Norden MIL VAX-I (SDCS).

Major CD/CPS interfaces with the other subsystems and systems are given in Table 4-1: the majority of the interfaces are RS232C asynchonous lines and 16-bit parallel interfaces to special purpose devices. Data rates on these lines are very low due to their being synchronous with the low speed telemetry data being transferred, or due to the nature of the devices (even when operated at device capacity; mostly control of TCS/ETI equipments). The highest data rates occur for disk, tape, and graphic output operations, but even with these devices operated at full speed, I/O limitations are not expected.

In addition to determining that a VAX class computer can perform satisfactorily in this environment, the existence of suitable interface controllers must also be determined. The following paragraphs address the CD/CPS areas of interest.

### 4.1.1 MODCOMP CLASSIC II/75 Computer System

This section describes the MODCOMP CLASSIC II/75 Computer System on which the SCCE system is currently based. It is presented to inform the reader of the current hardware, and to present the significant features and capabilities the Norden MIL VAX I and DEC VAX 11/780 must have.

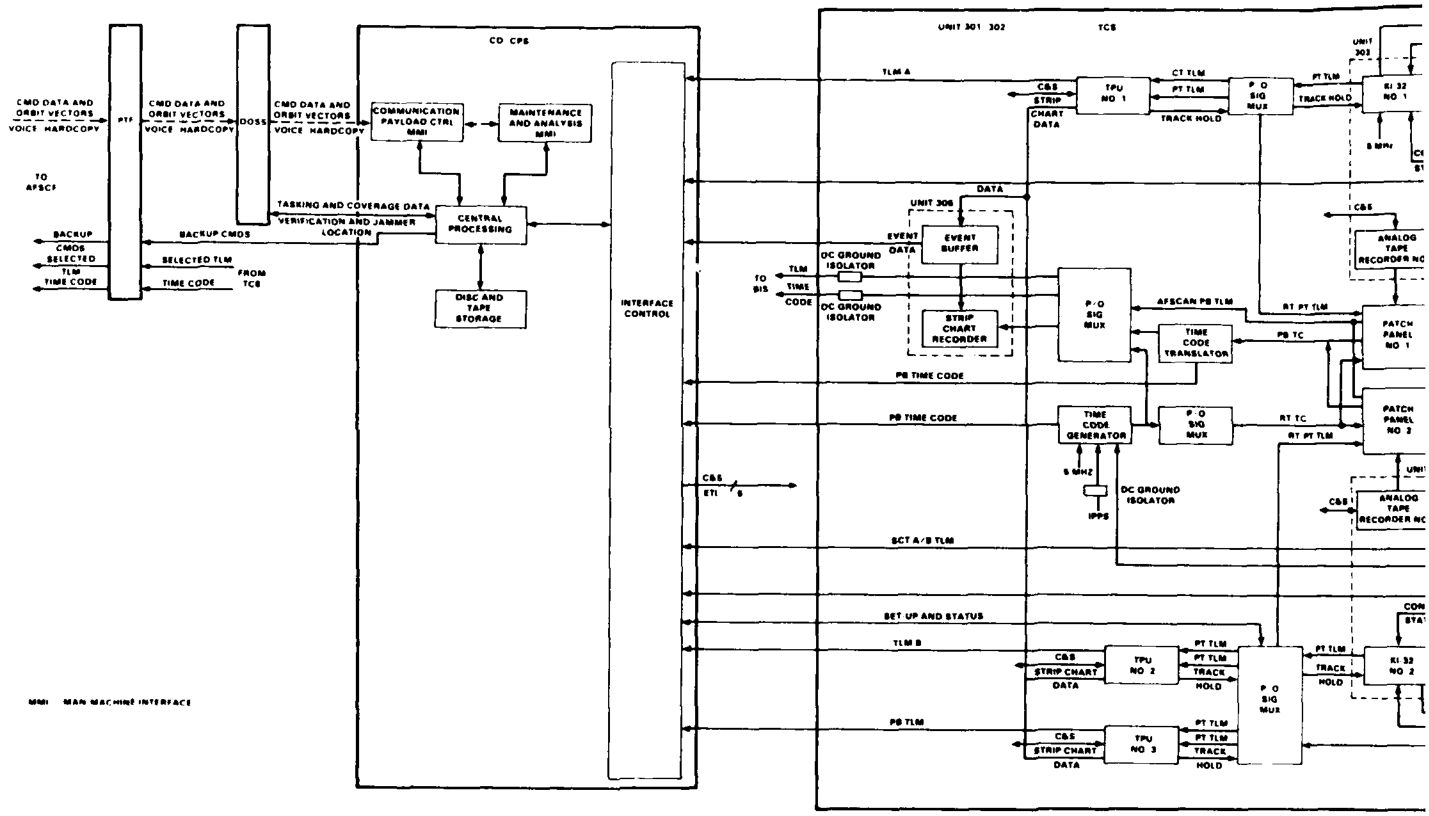
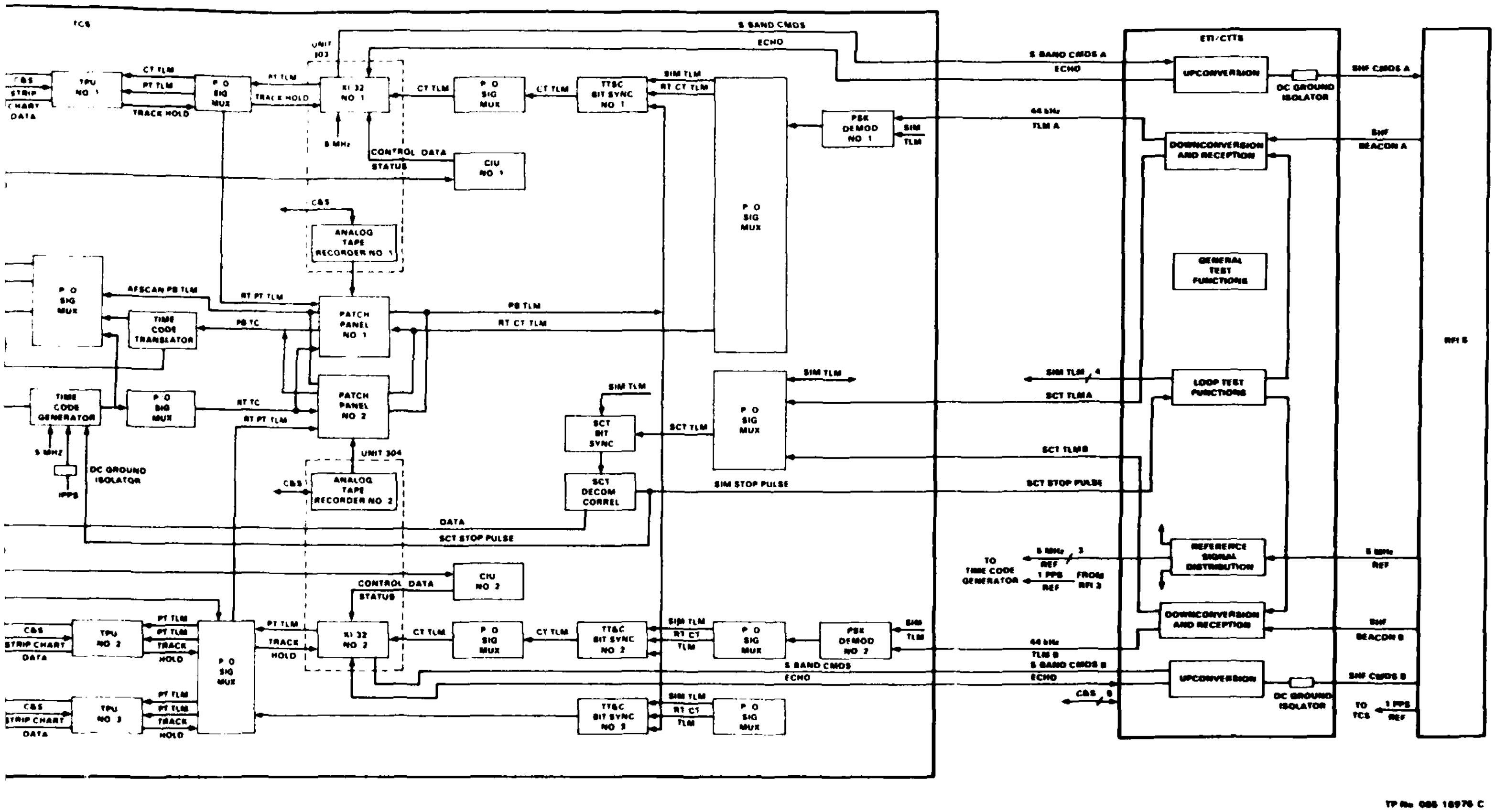


Figure 4-1. SCCE Architecture



-1. SCCE Architecture - Two Satellites

Table 4-1. CD/CPS Interfaces

| INTERFACE POINT | CD/CPS INTERFACE TYPE |
|---|---|
| TCS - D/A Converter | 16-bit parallel I/O |
| TCS - TPU #1 | 16-bit parallel I/O |
| TCS - TPU #2 | 16-bit parallel I/O |
| TCS - TPU #3 | 16-bit parallel I/O |
| TCS - SCT-TLM | 16-bit parallel I/O |
| TCS - TCT | 16-bit parallel I/O |
| TCS - TCG | 16-bit parallel I/O |
| TCS - SIG. MUX | 16-bit parallel I/O |
| TCS - CIU #1 | RS-232C, 9600 bps |
| TCS - CIU #2 | RS-232C, 9600 bps |
| TCS - SET UP TPU #1 | RS-232C, 9600 bps |
| TCS - SET UP TPU #2 | RS-232C, 9600 bps |
| TCS - SET UP TPU #3 | RS-232C, 9600 bps |
| TCS - TLM SIMULATOR | RS-232C, 9600 bps |
| ETI - UP CONVERTER #1 | RS-232C, 9600 bps |
| ETI - DOWN CONVERTER #1 | RS-232C, 9600 bps |
| ETI - UP CONVERTER #2 | RS-232C, 9600 bps |
| ETI - DOWN CONVERTER #2 | RS-232C, 9600 bps |
| AFSCF - DATA TRANSMISSION | RS-232C, 9600 bps |
| DOSS - DATA TRANSMISSION | RS-232C, 9600 bps |

4.1.1.1 Central Processor Unit (CPU)

The 16-bit oriented CPU has a fairly standard set of instructions expected of any minicomputer in its class. Instruction formats are 16-bit words (one or two, as applicable), and can reference both fixed point and floating point operands. Floating point operands consist of a 9-bit exponent plus 22-bit, 38-bit or 54-bit fractions required for single, double or triple precision respectively. An Extended Arithmetic Unit to process such floating point operations is integral to the CPU. Logical, shift, compare and test, branch, control, interrupt and call as well as I/O instructions are also provided.

Special machine instructions are provided to efficiently implement some FORTRAN statements, and thereby reduce the need for some assembly language.

Microprogramming (by customer) is possible to either extend the instruction set, or to achieve faster execution of high usage functions.

The CPU is rated at 0.96 MIPS (million instructions per second). It must be remembered that more instructions may be required on a 16-bit machine (such as this one) to equal the power of one on a 32-bit VAX. Hence, this may be a 0.8 MIPS machine when compared to a VAX of 1.0 MIPS. The efficiency of the compiler also affects this number. In its analysis, CSC has used .96 MIPS to represent the MODCOMP processing rate. The equivalent 16-bit processing rate of the Norden MILVAX and DEC VAX computers have been increased by 20% over their 32-bit performance.

4.1.1.2 Primary Memory

Semiconductor memory is used and has a maximum size of two megabytes. Memory mapping of applications modules to utilize scattered pages of real memory is used to increase efficiency of

memory usage. It is to be noted that although the literature refers to virtual addressing, the Classic II/75 does not offer virtual memory in the sense of paging to accommodate very large programs without programmer control.

Memory addresses can be interleaved up to four ways among memory modules to achieve a cycle time of 125 nanoseconds per 16-bit word. While this is faster than the MIL VAX I and VAX-11/780, the internal data bus of Classic II/75 is only half as wide as in a VAX and consequently the VAX units can more than make up their slower effective cycle time. There is no cache memory.

Error-correcting MOS memory is used to detect and flag multiple bit errors and to correct all single bit errors. Diagnostic circuitry and status registers are used to diagnose memory errors and provide automatic fault isolation. Memory usage is described in Table 4-2.

4.1.1.3 I/O Subsystem

The CLASSIC II/75 system for SCCE uses two I/O Processors (IOP) which can access memory directly to retrieve or store data involved in I/O to peripheral devices. Each IOP has two I/O busses which operate at up to two megabytes each. A wide variety of MODCOMP interfaces are available for attachment to the I/O busses. For the SCCE, the following are used for interface types to the telemetry and earth terminal equipments.

| | |
|---|---|
| MODCOMP 4805-2 | Parallel 16-bit I/O interface |
| MODCOMP 4806 | RS 232C line controller (up to 16 lines) |

Printers, printer-plotters, disk, and tape devices use specifically designed controllers.

Table 4-2. Memory Usage - MODCOMP CLASSIC II/75

| Memory User | Memory (Bytes) 1 Satellite | Memory (Bytes) 2 Satellites |
|---|---|---|
| Permanently Resident: | | |
| Operating System | 128K | 128K |
| Fortran Runtime Library | 30K | 30K |
| Common | 70K | 140K |
| SRE | 25K | 25K |
| Telemetry Acquisition | 70K | 140K |
| Beacon Acquisition | 30K | 60K |
| SUBTOTAL | 353K | 523K |
| Temporarily Resident | | |
| Tasks | 1,593K | 2,688K |
| Overlays | 1,407K | 2,397K |
| SUBTOTAL | 3,000K | 5,085K |
| Total All Software | 3,353K | 5,608K |
| Physical Memory Available | 2,000K | 2,000K |
| Remaining Memory (If all S/W is resident) | Not Feasible | Not Feasible |
| Remaining Memory for Dynamic Allocation of Temp, Res. Tasks | 1,647K | 1,477K |

4.1.1.3.1 MODCOMP Parallel I/O Interfaces

The MODCOMP 4805-2 parallel 16-bit interface controller is a general purpose unit which provides an interface to a user's device for control, status, and data transfers. There are 16 input, 16 output, 6 command, and 7 external status lines which may be used for device interfacing. Additionally, spare printed circuit board space is available for the user to implement special logic on the controller rather than in the device, if preferred. Table 4-3, MODCOMP 4805-2 Parallel I/O Interface Signals, presents the signals the user has available to work with for interfacing to user devices.

Parallel 16-bit I/O interfaces are used as indicated in Table 4-3. A comparison table showing parallel interface controller signals for both MODCOMP and Norden DEC systems is presented in a later section. It will be noted that some conversion engineering probably will be necessary to interface the telemetry and earth terminal equipment to the VAX-type computers.

4.1.1.3.2 MODCOMP RS232C Line Controller

The MODCOMP 4806-X Asynchronous Terminal Controller can accommodate up to 16 RS232C asynchronous lines added in groups of four lines at a time. The following features are provided:

- Programmable data rate (19.2kb/s maximum)
- Receive break detect
- Programmable frame size, stop bits and parity bit
- Echoplex Mode
- Channel wraparound
- Limited modem control
- Transmitter single buffer capability (switch selectable)

Table 4-3. MODCOMP 4805-2 Parallel I/O Interface Signals

| MODCOMP CLASSIC II/75 | DESCRIPTION |
|---|---|
| IBD00-IBD15 | 16 input data bits |
| OBI00-OB15 | 16 output data bits |
| EXTSIN | Interrupt Control |
| LDIBFN | Load input strobe |
| ODSTBN | Strobe generated on output data ready |
| | Strobe indicating CPU has taken user data |
| | Combination status and command bits |
| CB10N-CB15N<br>IST03N, 05N, | Command bits (6)<br>Status bits (7) |
| 11N-15N | (03N indicates device on)<br>(05N normally device error) |
| -- | True whenever UNIBUS is initialized |
| OCSTBN | Output command ready strobe |
| ODACCN | Device signals output data has been accepted |
| INBMTN | Signals device that input data buffer is empty. CPU has taken data (level signal, not pulses) |
| OBFFN | Output ready for device |
| BUSYN | Device busy status bit |
| INHBCN | Signal to prevent loading more input data from device until CPU has taken data |

Signal levels, waveforms, timing etc. are in accordance with the EIA RS-232C specifications. These lines operate intermittently at rates of 9600 bps.

4.1.1.4 Peripheral Storage Devices

Two major peripheral storage devices are used in the CLASSIC II/75 configuration within the SCCE. These are the MODCOMP 4195-2 magnetic tape subsystem and the MODCOMP 4178-2 Disk Drive subsystem.

4.1.1.4.1 MODCOMP 4195-2 Magnetic Tape Subsystem

The MODCOMP 4195-2 magnetic tape subsystem consists of a tape controller and daisy chain of up to three magnetic tape drive units. Each transport is a 75 inch per seconds drive with selectable recording densities of 800 or 1600 bits per inch. Transfer rate is 120KB/sec. Tapes are one-half inch wide, 9-track, and are IBM compatible. A tape formatter within the controller allows the recording modes to be phase-encoded or non-return to zero (inverted).

4.1.1.4.2 MODCOMP 4178-2 Moving Head Disk Subsystem

This dual ported magnetic disk drive used in the configuraton has a formatted capacity of 67 MB, average access time (AAT) of 30 ms, and I/O transfer rate of up to 1.2 MB per second. Each disk has its own controller, and daisy chains to one or more disks in order to ensure disk access sh ld either an input/output device or disk controller malfunction. In the current SCCE configuration, one disk is used exclusively as a system disk, one is used exclusively as a DSCS data disk, and the third is an on-line spare ready for use if one of the operational disks malfunctions.

4.1.1.5 MMI Peripheral I/O Devices

Peripheral devices used to interact with users during operation include the following:

#### 4.1.1.5.1 VT100 Alphanumeric Terminals

DEC VT100 Alphanumeric Terminals are used to interface to controllers in SCCE operational positions. These are standard monochrome RS232C devices operated at 9600 bps, and are used to enter system commands, data, and receive data/reports.

#### 4.1.1.5.2 Tektronix 4014-1 Graphic Terminal

Tektronix 4014-1 Graphics Terminals include a display, standard keyboard and a programmable function keyboard (PFK) (32 keys). Primary usage is for graphics displays such as satellite "footprint" plots etc. To save keystrokes and provide ease of operation, certain functions can be invoked by pushing specific keys on the PFK keyboard. When pushed and function selected, a lamp at that key is illuminated.

The terminal interfaces to the computer system by means of an RS232C asynchronous line operating at 9600 bps. Another RS232C line interfaces the terminal to a Versatec C-TEX-5 Graphics CRT Controller which enables transfer of graphic CRT data to the Versatec V80 Printer/Plotter. The C-TEX-5 is an electronic switch which selects either the terminal or a printer/plotter interface from the computer system as the source of graphic print information for the V80 printer. When one device is selected, the printer accepts data from that device and appears busy to the other.

#### 4.1.1.5.3 Versatec V80-11 Printer/Plotter

The Versatec V80 Printer/Plotter is used to function both as a printer and as a plotter (through dot-line printing). Use of dot-line printing enables the V80 to display any kind of graphics since the page image (including plots) is printed a line at a time (1/200 of an inch resolution). Plotting is performed at a rate of one inch per second.

In the print mode, the V80 prints 132 character lines at the rate of 1000 characters per inch. Paper width is eleven inches for both modes.

Interface to the computer is through a Versatec C-TEX-5 Graphics CRT Controller and in turn to a MODCOMP printer plotter interface. The C-TEX-5 allows the computer system and a single graphics terminal (RS232C) to share the V80 Printer Plotter.

4.1.1.5.4 MODCOMP 4242-21 Printer

The MODCOMP 4242-21 impact line printer (manufactured by Data Products, Inc.) is a 132 column, 1000 lines per minute device. Character set is 64 character ASCII. Paper widths up to B size (14-3/4 inches) can be accommodated.

4.2 SCCE Disk Storage

Three 67MB disks are used (Figure 4-2). The System Disk is fully loaded with operating system, spooler, roller, batch and scratch files. The operating system files include the MODCOMP operating system, system load modules, applications load modules, systems source library and FORTRAN library. The Data Disks contain the files needed to support the applications software. All three satellite data bases are located on Data Disk 1. Data Disk 2 provides a backup capability to be used in case of disk channel failure or controller failure.

4.2.1 SCCE Files

The basic SCCE file structure for the MODCOMP implementation is described in Table 4-4. Files are either uniquely associated with a specific satellite (either active or standby) or are fixed in size for the SCCE as a whole. As Table 4-3 shows, about 15 MB Bytes of storage are required to support each satellite, and an additional 4.5 MB completes the SCCE files. This file structure is not changed for the MIL VAX or DEC VAX based systems.

4.3 Software

The MODCOMP based software is described in Section 5.

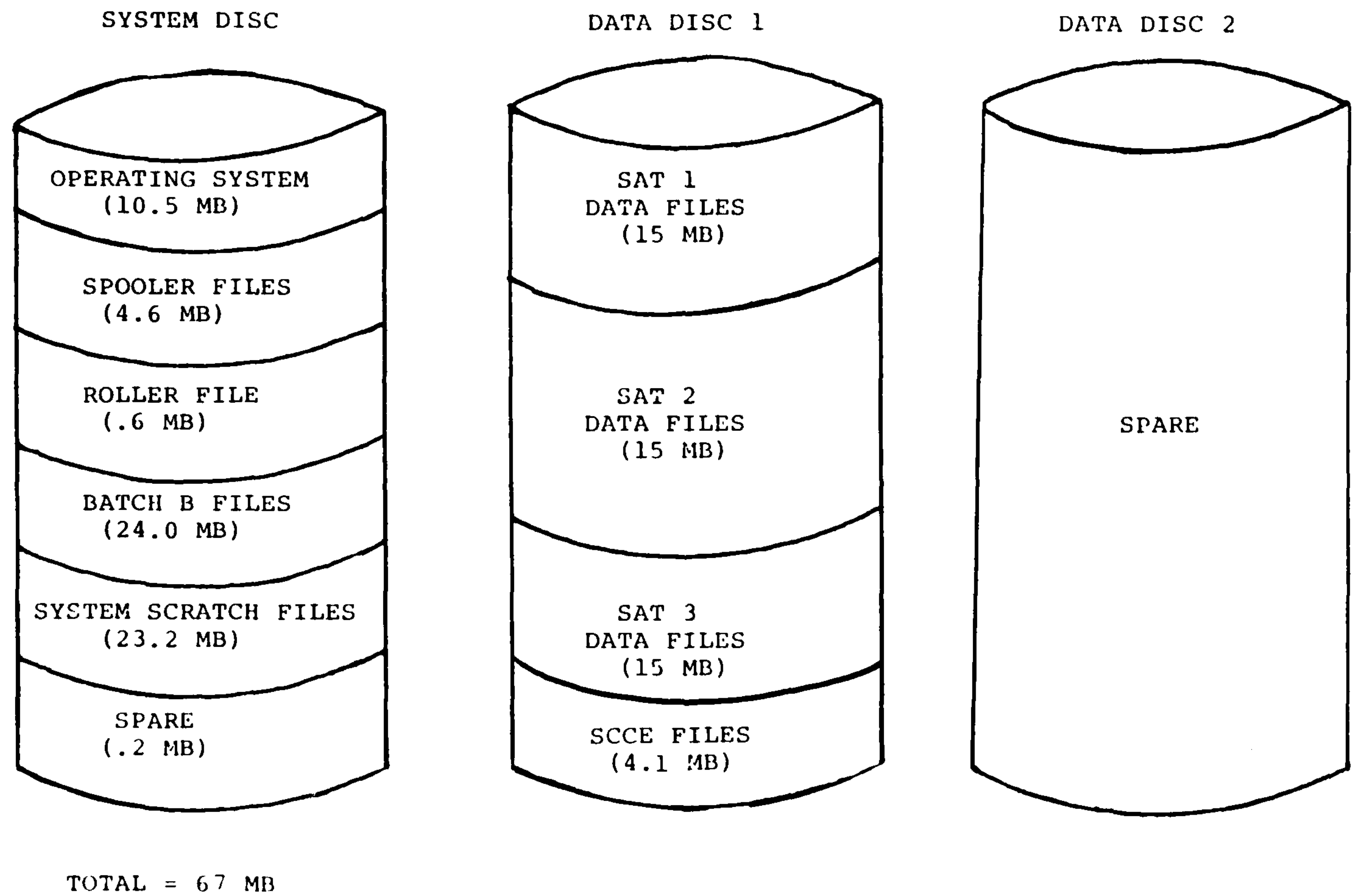



Figure 4-2. MODCOMP Disk Storage - Two Active Satellites

Table 4-4. SCCE File Description

| CPCI | FILE CATEGORY | FIXED (KB) | PER SATELLITE (KB) | TOTAL (KB) |
|---|---|---|---|---|
| TCP | MIF | 650 | | |
| | STATIC | 200 | | |
| | DYNAMIC USER DEFINED | 345 | | |
| | DYNAMIC DATA STORAGE | 200 | 11,100 | |
| | HISTORY | 3,100 | 256 | |
| | CATALOG | 19 | 27 | |
| | SUBTOTAL | 4,514 | 11,383 | |
| CCP | STATIC | | 2,500 | |
| | USER DEFINED | | 35 | |
| | DATA STORAGE | | 580 | |
| | SUBTOTAL | | 3,115 | |
| SCCE TOTAL | | 4,514 | 14,498 | - |
| 1 Active Satellite<br>1 Standby Satellite | | 4,514 | 28,996 | 33,510 |
| 2 Active Satellites<br>1 Standby Satellite | | 4,514 | 43,494 | 48,008 |

# 5.0 SOFTWARE

## 5.1 Software Description

### 5.1.1 General

The SCCE-unique software consists of applications software which performs the functions of the SCCE and systems software which adapts the computer to the specific configuration used. The software is summarized in Table 5-1. The Lines of Code listed in Table 5-1 are for the IPM SCCE which supports a single active satellite. The PSCCE uses functional duplicates of much of the IPM software to support a second active satellite. The functional duplicates do not require independent conversion for rehosting, though they do add configuration management efforts.

### 5.1.2 Applications Software

#### 5.1.2.1 Computer Program Configuration Items

The SCCE applications software consists of two Computer Program Configuration Items (CPCIs): Telemetry and Command Program (TCP) and Communications Configuration Program (CCP). Each CPCI consists of multiple Computer Program Components (CPC's) which are linked together to form the executable program. Also included in the applications software are the utilities and common data variables necessary to support each CPCI.

#### 5.1.2.2 Telemetry and Command Program

The Telemetry and Command Program provides the following capabilities for the DSCS III satellite from the SCCE:

a. Commanding of all satellite subsystems, including the Communications Subsystem.

b. Acquisition and processing of the satellite telemetry data.

c. Performance analysis of the satellite subsystems.

d. Configuration and control of the ground station.

Table 5-1. SCCE Software Summary

| SOFTWARE ELEMENT | FORTRAN LINES | ASSEMBLER* LINES |
|---|---|---|
| APPLICATIONS | | |
| TCP | 57,404 | 688 |
| CCP/ORBIT | 29,415 | 0 |
| UTILITIES | 17,383 | 3,888 |
| COMMON | 11,000 | 0 |
| COMMENTS | 115,780 | 5,000 |
| UNEXECUTABLE CODE** | 11,580 | 0 |
| AUXILIARY EXEC. ROUTINES | 0 | 26,406 |
| TOTAL (APPLICATIONS) | 242,562 | 35,982 |
| SYSTEM | | |
| MACROS | 0 | 22,400 |
| PROCEDURES | 0 | 5,300 |
| TOTAL (SYSTEM) | | 27,700 |
| TOTAL-SCCE | 242,562 | 63,682 |

*Includes all machine unique code

**FORMAT, DATA, specification statements

e. Jammer detection.

f. Verification of the Configuration of the Multiple Beam Antennas (MBAs).

g. Operator/Controller training assistance.

The TCP software system executes under the control of the SCCE operators and controllers. The operating system and the auxiliary executive functions provide executive and input/output routines for the applications software modules. Executive routines include task scheduling and dispatching on a priority basis, interrupt handling, and memory and device allocations. Input/output routines include communication with the CRTs and keyboards, data transfers to and from the SCCE ground station hardware, file management services, and printed outputs.

The TCP functions are divided into:

a. Real time functions.

b. Regularly scheduled functions.

c. Support functions.

d. Utilities.

Many of the real time and regularly scheduled functions can be initiated at any time by a request from the operator.

The real time (R/T) TCP functions consist of Telemetry Acquisition, R/T Satellite Performance Evaluation provided by the Telemetry Processing and MBA Configuration Verification functions, R/T Command Generation and Transmission, Jammer Detection, and R/T Display Generation. These functions are performed by core-resident and interactive modules which execute in the computer memory concurrently. Among the R/T functions, Telemetry Acquisition has the highest priority with Command Management the next highest. R/T Display Generation has the lowest priority.

The regularly scheduled TCP functions consist of Subsystem Analysis, Activity Report Generation, and Archival/Reload. These functions are all regularly scheduled on data span termination (i.e., approximately every two hours). They share the computer memory and resources with the R/T functions. Therefore, since their priorities are lower, they execute when the R/T functions are awaiting external input requests. Among the regularly scheduled functions, Archival has the highest priority and Activity Report Generation the lowest.

The support functions for the TCP CPCI consist of Static Data Base Generators, Command Sequence Generators, the Inter-Site Data Transfer Function, and the Training Scenario Generator. The support functions use the executive and I/O routines provided by the Operation System and the Auxiliary Executive functions to generate the data base required by the on-line functions from operator inputs, and to list and display data and generate reports from the data base for use by the operations personnel.

The TCP utility functions consist of routines to perform bit manipulation, file accesses, output formatting, numerical conversions, and error displays. These functions are invoked by other TCP functions. Therefore, their priorities vary according to the priority level of the routine making the call.

5.1.2.3 Communications Configuration Program

The Communications Configuration Program provides the following capabilities during various phases of the DSCS III mission:

a. Communications subsystem configuration control.

b. Control and analysis of the three MBAs.

c. Control and analysis of the Gimballed Dish Antenna.

d. Support of the above functions.

The CCP software system executes under the control of the SCCE Operators and Controllers. Operator requests are handled by the Sequence and Control function. Each CCP function, once initiated, interacts with the operator directly using the command CRT for those inputs required for execution.

The communications subsystem configuration control CCP functions consist of Antenna Connection, Primary/Redundant Component Selection, Jammer Detection Mode Selection, Transponder Channel Gain, RLM (Receive Level Monitor) Mode Selection, and Frequency Shift Selection. The control and analysis of the three MBA's and Gimballed Dish Antenna CCP functions consist of Selective Coverage, Jammer Nulling, Multiple Beam Antenna Command Sequence Generation, MBA Plotting, and Gimballed Dish Antenna Control. The CCP support functions consist of Jammer Location, Ephemeris and Ranging Data Generation, Message Encode/Decode Input/Output Handles, Static Data Base Generation, and Sequence and Control.

The CCP software system is an off-line, interactive, menu driven program. It is operated by keying in responses to menus and prompts displayed on any graphics or alphanumeric CRT to which the System Request Executive has access.

Table 5-2 summarizes the number of Computer Program Components (CPCs) and lines of FORTRAN and Assembly code for each software system. Table 5-3 lists the CPCs having embedded Assembler code. Note that, in general, the number of lines of comments is slightly greater than the number of lines of executable code.

5.1.3 System Software

The system software consists of macros and procedures.

Table 5-2. Application Software Summary

| SOFTWARE ELEMENTS | CPCs | FORTRAN LINES* | ASSEMBLER LINES* |
|---|---|---|---|
| TCP: | | | |
| REAL-TIME FUNCTIONS | 502 | 14,027 | 674 |
| REGULARLY SCHEDULED FUNCTIONS | 137 | 8,790 | 0 |
| SUPPORT FUNCTIONS | 138 | 14,579 | 14 |
| TCP TOTAL | 777 | 57,404 | 688 |
| CCP FUNCTIONS | 179 | 29,415 | 0 |
| UTILITIES | 253 | 17,383 | 3,888 |
| COMMON | - | 11,000 | 0 |
| COMMENTS | N/A | 115,780 | 5,000 |
| UNEXECUTABLE CODE** | N/A | 11,580 | 0 |
| AUXILIARY EXEC. ROUTINES | N/A | 0 | 26,406 |
| TOTAL | 1209 | 242,562 | 35,982 |

*Excluding Comments, Unexecutable Code
**FORMAT, DATA, Specification Statements

Table 5-3. CPCs With Embedded Assembler

| LOAD MODULE | CPC | LINES OF EMBEDDED ASSEMBLER |
|---|---|---|
| CMDCT1-CMDVF1 | TCM241 | 19 |
| CMDCT1 | TCM245 | 13 |
| CMDCT1 | TCM24B | 25 |
| CMDCT1 | TCM300 | 14 |
| CMDSEG | TCG110 | 14 |
| CMDVF1 | TCT3B1 | 59 |
| CMDVF1 | TCT3B2 | 34 |
| CMDVF1 | TCT3B3 | 88 |
| SRE | TEX150 | 24 |
| SRE | TEX170 | 5 |
| SRE | TEX180 | 16 |
| TOTAL | | 311 |

5.1.3.1 Macros

Many of the operations that the MODCOMP operating system performs on behalf of the user are implemented as tasks called system services. Most of these tasks are linked as part of the executive and reside in system space; others are contained in privileged libraries. Some services are invoked directly by the application programs. Others are called on behalf of the user bythe MODCOMP operating system. MODCOMP System services performs the following functions:

- o Task Scheduling
- o Inter-task communication
- o Memory Allocation
- o Logical I/O Handling
- o File Manager
- o Operator Communication
- o Program Development Facility
- o High Level Language Support
- o Task loading
- o Automatic roll-in/roll-out

Software has been developed to perform some of these functions. These system software routines are known as macros, written in MODCOMP assembly language. A brief description of typical macros is given below.

COMMAC. This macro, the Communication Macro, transmits variable length collections of data between tasks. Messages flow along distinct communication paths known as channels. Tasks use the message service for synchronization as well as information transfer.

FMAMAC the File Manager Macro, FMAMAC organizes, maintains and services multilevel files. File Manager also supports FMLIST (List Utility) and FMSADE (Save/Restore Utility) which operate as a standard processor within the File Manager Subsystem.

LIOMAC Logical I/O System Macro performs task scheduling and monitors I/O transactions to peripheral controllers.

Many of these functions may be provided by a computer operating system, e.g., VAX/VMS. CSC is unable, at this time, to state how many of these functions will be rewritten. In costing and conversion estimates, CSC has assumed the worst case, that all macros must be reprogrammed.

5.1.3.2 Procedures

A procedure or command procedure is a file containing a predefined sequence of commands to perform certain actions. Common uses for a command procedure include constructing sequences of commands one frequently uses during interactive terminal sessions, and defining a batch job stream to submit from a terminal session or a system card reader. In its simplest form, a command procedure consists of one or more command lines for the command interpreter to execute. The command procedures are written in MODCOMP command language.

Examples of the functions performed by MODCOMP procedures are:

a. Build a batch job.

b. Create a disk file.

c. Update a system library.

d. Create a single system disk.

These procedures are machine dependent. They will have to be rewritten for each machine on which the SCCE is hosted.

## 5.2 Software Portability and Conversion

A major problem with program conversion is that compiler dialects for the same language may differ among different vendors. The VAX-11 MVS FORTRAN and the MODCOMP NASA EXTENDED FORTRAN-78 are both based on the American National Standard (ANS) FORTRAN X3.9-1978; however, there are certain incompatibilities between the two FORTRAN implementations. These incompatibilities are described in Sections 5.2.1 through 5.2.4. MODCOMP FORTRAN programs can be modified so that they produce the intended result under the VAX-11 FORTRAN compiler.

FORTRAN programs consist of FORTRAN statements, which define a computing procedure, terminated by an END statement and optional comments. Statements can be grouped into two general classes, executable and nonexecutable, which are described in the following sections.

### 5.2.1 Nonexecutable Statements

This section describes the nonexecutable incompatible statements that will require a minimum conversion effort. Nonexecutable statements describe data arrangements and characteristics, and provide editing and data-conversion information.

#### 5.2.1.1 Debug Statement Indicator

Debug statements are FORTRAN statements that are treated as source text or comments by some compilers, depending on the compiler directive that is specified. The MODCOMP FORTRAN programs under review use a letter "X" in column 1 to designate debug statements. The VAX-11 FORTRAN compiler will allow the use of the letter "D" in column 1 to designate debugging statements. Each continuation line of a debug statement must have the letter "D" in column 1 as well as the continuation indicator in column 6.

### 5.2.1.2 INCLUDE STATEMENT

The INCLUDE statement causes the contents of a designated file to be incorporated in the FORTRAN compilation directly following the INCLUDE statement. The specifications of the VAX-11 FORTRAN and the MODCOMP FORTRAN are somewhat different as described in Table 5-4.

Table 5-4. INCLUDE Statement

| MODCOMP FORTRAN | VAX-11 FORTRAN |
|---|---|
| INCLUDE dir/file,list-option, rewind-option | INCLUDE 'file specification/ list-option' |

File specifications in VAX have the form: [directory] file name.file type.version.

directory — identifies the name of the directory under which the file is cataloged. Directory name can be delimited with a square or angular bracket.

filename — identifies file by its name. It can be 9 characters long.

filetype — describes the kind of data in the file; it can be up to 3 characters long.

version — defines which version of the file is desired. Versions are identified by a decimal number.

In MODCOMP FORTRAN an INCLUDE statement provides both the list and the rewind option. However, a FORTRAN INCLUDE statement in VAX provides only the list option.

The VAX-11 FORTRAN INCLUDE statement is limited to 40 continuation lines.

#### 5.2.1.3 Explicit Type Statements

MODCOMP FORTRAN provides for the explicit definition of real variables in 4, 6 or 8 bytes; however, VAX-11 FORTRAN only provides for an explicit real variable of 4 and 8 bytes. MODCOMP FORTRAN explicit REAL*6 variables should be changed to REAL*8 variables for the VAX-11 FORTRAN, which means 2 additional bytes of core is used. These two additional bytes will not significantly affect the total amount of memory used.

#### 5.2.1.4 FORMAT Statement

There were two uses of the FORMAT statement that are incompatible between the VAX-11 and MODCOMP FORTRAN compilers. They are the use of the first character in the FORMAT statement for vertical spacing when a record is printed, and the use of the double quote (").

The VAX-11 FORTRAN compiler does not recognize a vertical spacing character unless it is enclosed in single quotes (' '). For character transmission, MODCOMP allows both the single quote and the double quotes in the FORMAT statement. The VAX FORTRAN compiler also does not recognize the double quote as it is used in the MODCOMP FORTRAN FORMAT statements. The incompatibilities are indicated in Table 5-5.

Table 5-5. FORMAT Statement

| MODCOMP FORTRAN | VAX-11 FORTRAN |
|---|---|
| FORMAT (0//) | FORMAT ('0'//) |
| FORMAT ("ENTER YES/NO") | FORMAT ('ENTER YES/NO') |
| FORMAT ('ENTER YES/NO') | FORMAT ('ENTER YES/NO') |

#### 5.2.1.5 Integer String Statements

There are several places in the MODCOMP FORTRAN programs where the INTEGER type statement in conjunction with a DATA statement is used to specify string data. The VAX-11 FORTRAN compiler will not recognize the MODCOMP FORTRAN integer string constructs. The differences are illustrated below in Table 5-6.

Table 5-6. Integer String Statement

| MODCOMP FORTRAN | VAX-11 FORTRAN |
|---|---|
| INTEGER*2 MSG(4) | CHARACTER*2 MSG(4) |
| DATA MSG/'01020304'/ | DATA MSG/'01','02','03','04'/ |

### 5.2.2 Executable Statements

This section describes those executable statements which are incompatible that will require conversion to the VAX-11 FORTRAN constructs. Executable statements describe the actions of the FORTRAN program.

#### 5.2.2.1 Formatted Direct Access Input/Output Statements

Formatted direct access input/output (I/O) transmits character data to and from files on a direct access device. The VAX-11 FORTRAN compiler does not accept the END parameter in a formatted direct access READ or WRITE statement. However, the MODCOMP compiler allows an END parameter. All formatted READ and WRITE statements that have the END parameter must be converted to the VAX-11 FORTRAN form as indicated below in Table 5-7.

Table 5-7. Input/Output Statement

| MODCOMP FORTRAN | VAX-11 FORTRAN |
|---|---|
| READ (unit'rec#,frmt,ERR=s, END=s)list | READ (unit'rec#,frmt,ERR=s) list |

s=statement label

5.2.2.2 ENCODE/DECODE Statement

The ENCODE and DECODE statements transfer data according to format specifiers. Data transfers are between variables or arrays in the FORTRAN program and translations are from internal to character form or vice versa. The ENCODE statement is similar to a WRITE statement and the DECODE statement is similar to a READ statement. The differences between the MODCOMP compiler and the VAX-11 FORTRAN compiler ENCODE/DECODE statement are indicated below in Table 5-8.

Table 5-8. ENCODE/DECDOE Statement

| MODCOMP FORTRAN | VAX-11 FORTRAN |
|---|---|
| INTEGER*2 MSG(4)<br>INTEGER LENGTH<br>ENCODE(#char,frmt,MSG,LENGTH)<br>list | CHARACTER*8 MSG<br>INTEGER LENGTH<br>ENCODE(#char,frmt,MSG)<br>list<br>LENGTH=LEN(MSG) |

As illustrated in the table above, MODCOMP FORTRAN has an optional argument in its ENCODE statement which allows one to determine the length of the character string being transferred. This capability is absent in the VAX-11 FORTRAN compiler; however, one may use the instrinsic LEN function for this purpose. The LEN function cannot be used to determine the length of an INTEGER variable; therefore, all strings that the LEN function must act upon must be defined as CHARACTER variables as shown in the table above.

The DECODE statement form is the same as the ENCODE statement. Therefore, it is not illustrated or discussed.

5.2.2.3 Arithmetic IF Statement

The arithmetic IF statement transfers control to one of three statements, based on the value of an arithmetic expression, under most compiler dialects. However, the MODCOMP FORTRAN compiler allows one to exclude one or more statement numbers, wherein control transfers to the next executable statement. The VAX-11 FORTRAN compiler will not allow one to exclude statement numbers. Therefore, all MODCOMP FORTRAN code which has this variation of the arithmetic IF statement must be converted. Table 5-9 below illustrates the difference.

Table 5-9. Arithmetic IF Statement

| MODCOMP FORTRAN | VAX-11 FORTRAN |
|---|---|
| IF (expression) $s_1,,s_3$<br>I=J $s_2$ | IF (expression) $s_1,s_2,s_3$<br>CONTINUE<br>I=J |

$s_n$ = Statement labels

### 5.2.3 Embedded Assembly

The VAX-11 FORTRAN compiler does not allow embedded (in-line) assembly language code within a FORTRAN program; however, several MODCOMP FORTRAN programs have embedded assembly code. The embedded assembly code can be replaced with a call statement to a separate assembly language subroutine if the instructions must be written in assembly language code.

### 5.2.4 Recursive Coding

A subroutine that can be evoked from within itself and from within another procedure is called a recursive subroutine. Each repetition is usually dependent upon the result of the previous repetition, and data storage is re-created for each calling level. There is no indication that this feature was used in any of the programs that were reviewed. However, it is a feature of the MODCOMP FORTRAN compiler. The VAX-11 FORTRAN compiler does not have a recursive capability.

## 6.0 SDCS-MIL VAX I SYSTEM

### 6.1 SDCS Architecture

Figure 6-1 illustrates the SDCS Architecture to support one satellite. All equipments for the second telemetry stream (including the second set of up/down converters) have been removed. TPU#3 and associated equipment have been left in as redundant equipment (as in the two satellite configuration).

Major interface types are the same as for the two satellite systems, but quantities have been reduced as appropriate to reflect support of only one satellite. Table 6-1 gives the computer interface requirements.

The computer system to be used in the SCDS CD/CPS is a Norden System MIL VAX I as described below. It can fully replace the Classic II/75 system used in the current SCCE, especially with only one satellite being supported. With respect to schedule, it should be noted that the MIL VAX II will be available in time for implementation, and should be considered. It has one-third less weight, significantly reduced space requirements, costs less and will have 40% more computer power.

Because information on the MIL VAX II was not available to CSC at the start of this study, in its analysis CSC has used the MIL VAX I as the target computer. However, the MIL VAX II has a superior cost-performance profile, and should be used in any MIL VAX implementation of the SCCE.

Three chasses are used to house the computer system electronics: CPU chassis, power-I/O chassis and an expansion chassis. The CPU chassis contains the CPU and up to four megabytes of memory (one-half megabyte per card). Also contained within are the two UNIBUS controllers and the two CMI disk interface controllers. One UNIBUS leads to the power I/O chassis while the second goes to the expansion chassis.

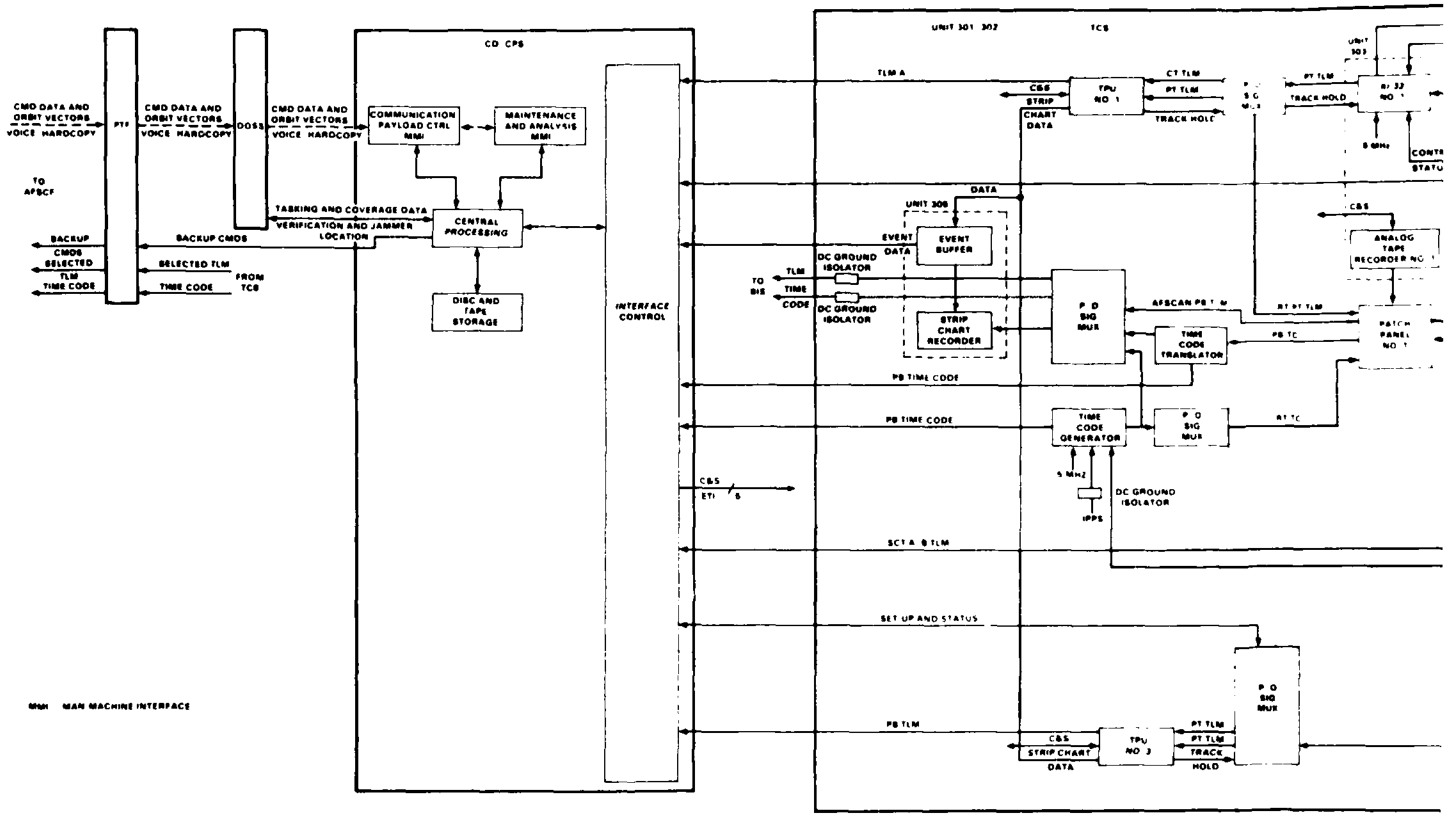
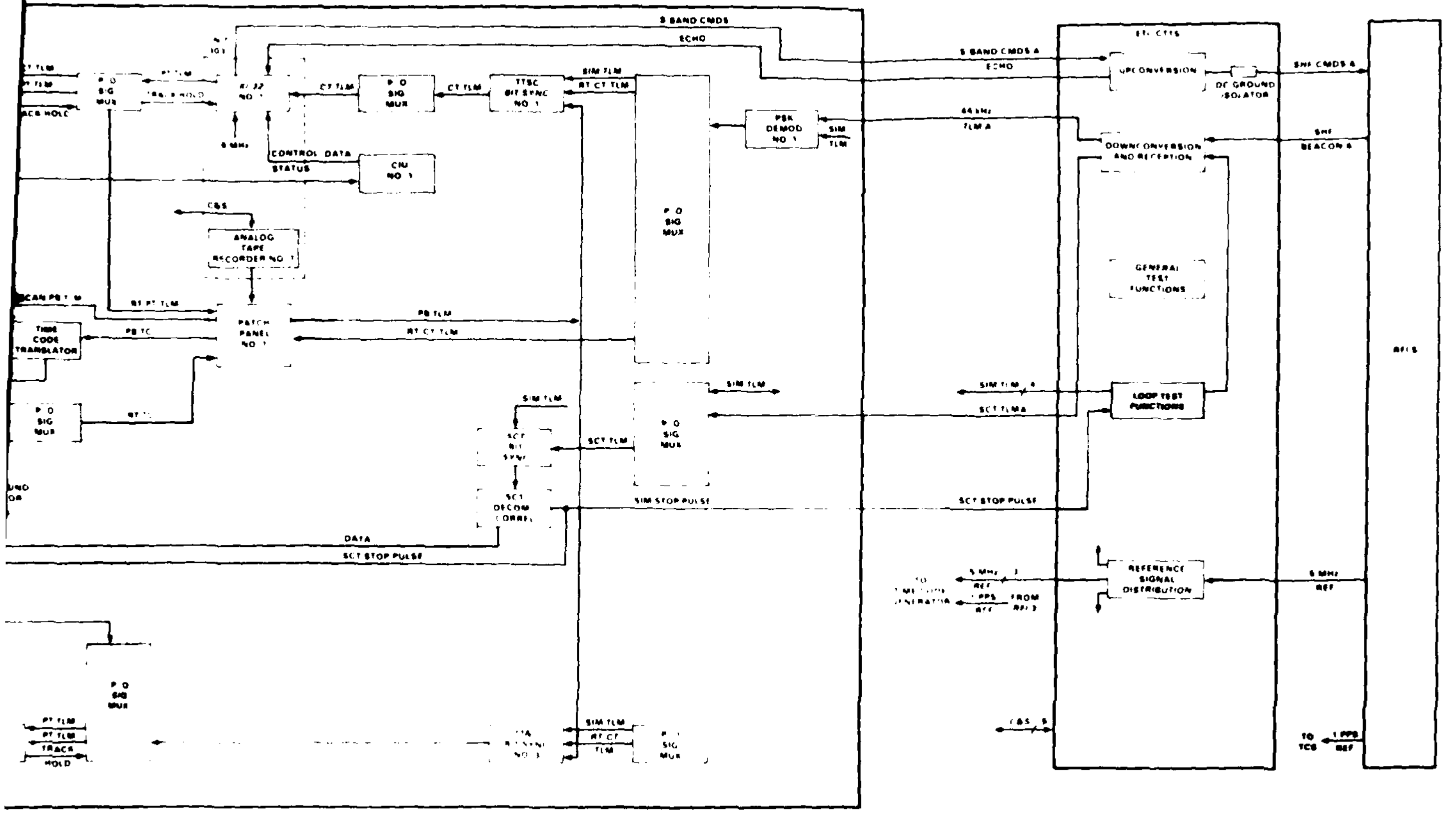



Figure 6-1. SDCS Architecture -




TP No 065 15976 C

)CS Architecture - One Satellite

2

Table 6-1. CD/CPS Interfaces

| INTERFACE POINT | CD/CPS INTERFACE TYPE |
|---|---|
| TCS - D/A Converter | 16-bit parallel I/O |
| TCS - TPU #1 | 16-bit parallel I/O |
| TCS - TPU #3 | 16-bit parallel I/O |
| TCS - SCT-TLM | 16-bit parallel I/O |
| TCS - TCT | 16-bit parallel I/O |
| TCS - TCG | 16-bit parallel I/O |
| TCS - SIG. MUX | 16-bit parallel I/O |
| TCS - CIU #1 | RS-232C, 9600 bps |
| TCS - SET UP TPU #1 | RS-232C, 9600 bps |
| TCS - SET UP TPU #3 | RS-232C, 9600 bps |
| TCS - TLM SIMULATOR | RS-232C, 9600 bps |
| ETI - UP CONVERTER #1 | RS-232C, 9600 bps |
| ETI - DOWN CONVERTER #2 | RS-232C, 9600 bps |
| AFSCF - DATA TRANSMISSION | RS-232C, 9600 bps |
| DOSS - DATA TRANSMISSION | RS-232C, 9600 bps |

### 6.1.1 SDCS Computer System Architecture

Figure 6-2 presents the mobile SCCE computer system architecture based around the Norden MIL VAX I. Peripherals are listed in Table 6-2.

Table 6-2. SCDS CD/CPS Peripherals

| QUANTITY | DESCRIPTION |
|---|---|
| 2 | Magnetic Disk Drives (134 MB each) |
| 1 | Magnetic Tape Drive [1] |
| 2 | Printer/Plotters |
| 4 | Graphics/A-N CRTs |

[1] Shared with DECS

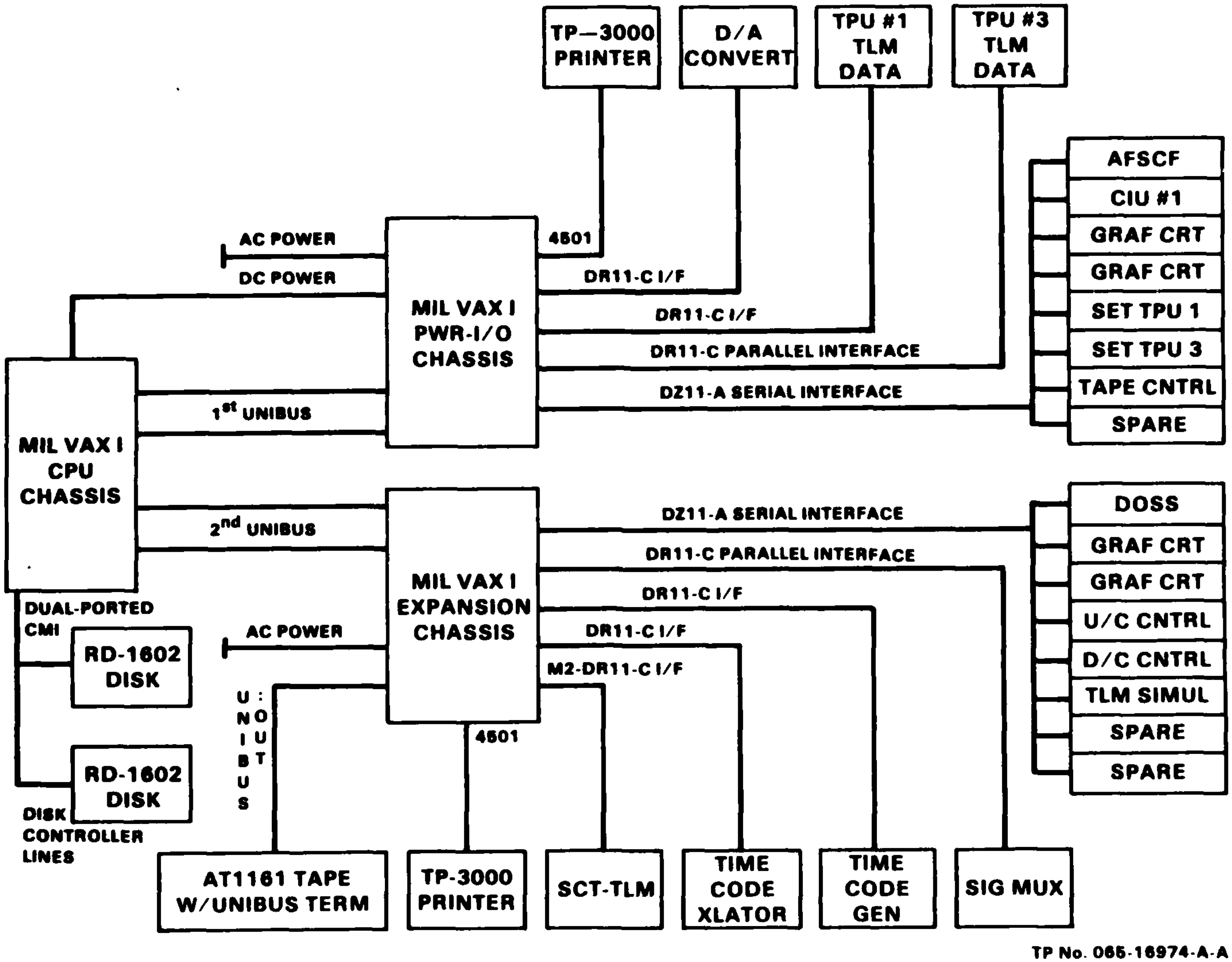



Figure 6-2. MIL VAX I Configuration

The power I/O chassis contains the power supply for the CPU chassis as well as for its own use. Additionally, it has nine I/O slots which can hold various peripheral I/O interface boards.

6.1.1.1 Interfaces

The power I/O chassis, UNIBUS #1, supports the following peripheral interfaces:

- DZ11-M 8 channel RS-232C serial interfaces (see below)
- DR11-C parallel interface to the Telemetry Processing Unit (TPU) #1
- DR11-C parallel interface to the Telemetry Processing Unit (TPU) #3
- DR11-C parallel interface to the D/A converter
- Norden 4501 printer/plotter interface to the Miltope TP-3000 printer

The DZ11-M 8 channel RS-232C serial interface supports the following asychronous lines (all at 9600 bps):

- Modem on communication line to AFSCF
- Two directly connected data lines to A/N graphics CRT's
- Directly connected data line to TPU#3 set up controller
- Directly connected data line to analog tape controller
- Directly connected data line to Telemetry simulator set up controller
- One line is spare

The expansion chassis contains its own power supply for its 28 I/O slots. Attached to UNIBUS #2 from the CPU chassis, the expansion chassis uses 8 slots to satisfy peripheral interface requirements. The UNIBUS #2 is extended out of the expansion

chassis to the AT1161 magnetic tape controller which is built into the magnetic tape drive itself. This UNIBUS also has the following telemetry support interfaces:

- o DZ11-M 8 channel serial interface (see below)
- o DR11-C parallel interface to the signal multiplexer
- o DR11-C parallel interface to the time code generator
- o DR11-C parallel interface to the SCT-TLM
- o TP-3000 printer interface
- o AT1161 magnetic tape interface built into the magnetic tape controller

The DZ11-M 8 channel RS232C serial interface supports the following asynchronous lives (all at 9600 bps):

- o Interface with DSCSOC LAN
- o Two directly connected data lines to A/N graphics CRTs
- o Directly connected line to D/C #1 controller
- o Directly connected line to U/C #1 controller
- o Directly connected line to computer interface unit #1 (CIU#1)
- o Directly connected line to the Telemetry Simulator
- o One line is spare

Assignment of peripheral I/O was accomplished by considering the I/O load and splitting it across the two UNIBUSs. Since there are two TPU telemetry ports, but with only one active at a given time, they are assigned to the same UNIBUS (#1). The SCT telemetry, which would be active simultaneously with one TPU telemetry stream, is assigned to the second UNIBUS. It has a lower throughput as do the time code translator, time code generator, and control to the signal multiplexer, which are also assigned to the second UNIBUS. The D/A converter is assigned to the first UNIBUS.

There are two printer/plotter and four graphic CRTs which are all considered potentially to be equally utilized. Therefore one printer/plotter and two graphic CRTs are assigned to each UNIBUS.

The AT1161 magnetic tape drive is assigned to the second UNIBUS since, when it is active, it presents a significant activity level on the UNIBUS. It is considered remotely possible that the telemetry acquisition could be interfered with occasionally during data span archiving. Hence, it is placed on the UNIBUS #2 which does not handle TPU telemetry stream.

I/O loading on RS-232C serial lines is similarly considered to split the data load. The heaviest users of the DZ11-M are considered to be the data communications lines to the DOSS and AFSCF as well as the four graphic CRTs. The DZ11-M on UNIBUS #1 is assigned one data communications line and two graphic CRTs. The remaining data communications line and two graphic CRTs are assigned to UNIBUS #2. Following this, the data, control and status lines for various controllers (all of which are low throughput users) are evenly distributed across the two DZ11-Ms.

## 6.2 Norden MIL VAX I Computer System

### 6.2.1 System Description

This section describes the Norden MIL VAX I which will be used in the SDCS. The MIL VAX I is a high performance, multiprogrammable system oriented toward real-time, time sharing data processing applications. In general it is designed as a ruggedized, militarized version of the Digital Equipment Corporation VAX-11/780. As a general comparison, it is computationally equivalent and has only slightly less I/O throughput capability.

### 6.2.2 Central Processor Unit

The MIL VAX I is a VAX-11/750 architecture unit with the power of a VAX-11/780. The CPU is designed around a 32-bit architecture and a virtual memory system to ensure the highest throughput while preserving its ability to respond to interrupts and changing application software demands at any moment. Addressing with 32 bits permits direct addressing up to four billion bytes of virtual memory. The instruction set includes fixed point, floating point, string/byte manipulation, jump, subroutine and extensive I/O calls, logical bit field, operations and software generated interrupt instructions. Sixteen general purpose 32-bit registers can be used as index, base, accumulators, and temporary storage. A stack mechanism is implemented through use of special stack instructions. An optional floating point accelerator is available to increase CPU efficiency in dealing with floating point numbers. Floating point numbers addressable by hardware include single (32 bits) and double (64 bits) precision.

An address translation buffer provides a cache of likely to be used physical addresses. This cache reduces the amount of direct CPU time to compute such addresses and improves CPU efficiency as a result. To further improve performance an 8 byte pre-fetch instruction buffer is used. Data is fetched in such manner as to overlap processing and to be ready to provide data to the CPU. Dramatic improvement occurs when additional memory cycles would have been wasted while the CPU waited for data not aligned or which cross 32-bit longword boundaries. An optional 24KB customer writeable Control Store is available for customers who need to augment the speed and power of the basic machine with customized instructions or functions. The CPU can execute 1.0 MIPS (32-bit instructions).

### 6.2.3 Primary Memory

The MIL VAX I currently supports up to four megabytes of semiconductor real memory. In the fourth quarter of 1985, it will be able to support eight megabytes in the same cabinet through use of new Norden memory boards. The VAX VMS operating system will support only eight megabytes of real memory at this time. Upon expansion of VMS capabilities, Norden will support 16 megabytes of real memory in the same cabinet space used by four megabytes today.

An 8 KB associative cache memory is used to reduce the 1.8 microsecond worst-case access to memory to 290 nanoseconds. While slower than a comparable 250 nanoseconds for the MODCOMP, the VAX CPU can execute slightly more MIPS due to its 32-bit data busses for data transfer and other aspects of such an 32-bit architecture, and thereby overcome the MODCOMP memory cycle time advantage. Memory addresses are also interleaved, which reduces waiting time for memory reference by the CPU or I/O device active at any given moment.

An error checking and correcting (ECC) scheme is provided which can detect all double bit errors and detect/correct all single bit errors. Eight ECC check bits are stored with each quadword (64 bits data + 8 ECC bits).

Battery backup for the dynamic MOS semiconductor memory is available as an option. It is capable of supporting four megabytes for 10-15 minutes of power outage.

### 6.2.4 I/O Subsystem

The MIL VAX I has two major I/O busses for peripheral devices, one for controllers that connect to the high performance computer memory interconnect (CMI) backplane, and the other for UNIBUSSES (of which there are two, maximum).

The disk subsystem will be connected to the CMI which will ensure high I/O performance to accommodate system and application software disk I/O. The slower UNIBUSSES will be used for all other peripheral I/O requirements such as magnetic tape, CRT's, telemetry data acquisition, control, and status of uplink/downlink equipment, etc.

6.2.4.1 Parallel I/O Interface

The DR-11C is a 16 bit parallel interface which can be used to replace the MODCOMP 4805-2 parallel interface. Table 6-3 shows the signal lines for data, control and status.

It may be necessary to provide some interface circuitry between the DR-11C and the specific piece of uplink/downlink or telemetry equipment to provide voltage level conversion or to provide handling of all control and status signals necessary to the DR11-C and the equipment (interfaces were originally designed for MODCOMP equipments).

6.2.4.2 RS232C Asynchonous Line Controller

The DM11-C will provide eight RS232C asynchronous lines per controller. Limited modem control is available with the DM11-C. Specifications on the signal and data lines conforms to the EIA RS232C standard. Therefore, it should be possible to replace all MODCOMP/SCCE RS232C interfaces by use of the DM11-C. Two such controllers will be required to accommodate all RS232C lines in the mobile SCCE for DOSS and AFSCF data transmission, as well as for control/status of the uplink/downlink and telemetry equipment.

Speed of line operations is 9600 bps in all cases, which is well within the 19.2 kbps limit of the DM11-C.

6.2.4.3 Printer/Plotter Interface

The printer/plotter interface is a Norden manufactured controller for the Miltope TP-3000 Thermal Printer/Plotter.

Table 6-3. Parallel I/O Interface Signals

| NORDEN MIL VAX I & DEC VAX-11/780 | MODCOMP CLASSIC II/75 | DESCRIPTION |
|---|---|---|
| IN00-IN15 | IBD00-IBD1S | 16 input data |
| OUT00-OUT15 | OBI00-OB15 | 16 output data bits |
| REQUEST A, B | EXTSIN | External interrupt line |
| LDINPREG | LDIBFN | Load input strobe |
| NEW DATA READY | ODSTBN | Strobe generated on output data ready |
| NEW DATA READY LO | | Strobe generated when low output byte loaded |
| NEW DATA READY HI | | Strobe generated when high output byte loaded |
| DATA TRANSMITTED | See INBMTN | Strobe indicating CPU has taken user data |
| CSR0, 1,2,3 | | Combination status and command bits |
| -- | CB10N-CB15N | Command bits (6) |
| -- | IST03N, 05N, | Status bits (7) |
| | 11N-15N | (03N indicate device on) (05N normally device error) |

Table 6-3. Parallel I/O Interface Signals (Cont'd)

| NORDEN MIL VAX I & DEC VAX-11/780 | MODCOMP CLASSIC II/75 | DESCRIPTION |
|---|---|---|
| INIT | -- | True whenever UNIBUS is initialized |
| -- | OCSTBN | Output command ready strobe |
| -- | ODACCN | Device signals output data has been accepted |
| See DATA TRANSMITTED | INBMTN | Signals device that input data buffer is empty. CPU has taken data (level signal, not pulses) |
| | OBFFN | Output ready for device |
| | BUSYN | Device busy status bit |
| | INHBCN | Signal to prevent loading more input data from device until CPU has taken data |

6.2.5 Peripheral Storage Devices

6.2.5.1 Miltope AT1161 Magnetic Tape Subsystem

While the fixed SCCE has one magnetic tape controller and three tape drives, the mobile configuration will have a controller and only one tape drive. Miltope AT1161 will be used as the ruggedized, militarized magnetic tape drive. The controller for this magnetic tape drive will be a four board unit manufactured by Norden.

Characteristics of the 9-track IBM compatible magnetic tape subsystem are 75 ips drive, 800/1600 bps, and NRZI recording mode.

6.2.5.2 Miltope RD160 Magnetic Disk Subsystem

The disk subsystem will use two ruggedized Miltope RD160 disk drives and a Norden manufactured controller. Each disk is dual ported and has its own controller which is connected to the CMI for high performance. The second port of each disk is connected to the other disk controller which provides redundancy and ensures disk access in case of controller failure.

Characteristics of each disk drive are 134 MB of formatted disk space, 26 msec average access time, and a transfer rate of 1.28 MB per second.

There is a significant difference in how these disks will be used compared to the MODCOMP disks. The MODCOMP configuration uses one disk as a system disk (whereas VAX VMS requires two disks, although not 100% dedicated), one disk for application programs and files (whereas the two disks of the MIL VAX I will have to be used) and has one spare disk. The SCDS/MIL VAX I will have no spare disk on-line.

The Miltope disk uses Winchester technology which means the disk platters and read/write heads are in one sealed unit. This unit is easily removed by unscrewing four thumb screws and another disk unit placed within. If a head crash occurs, a new Winchester unit can be put in place and operation resumed. Of course, there will be a loss of data on the crashed disc in most cases.

6.2.5.3 Miltope TP-3000 Printer/Plotter and Interface

The Miltope module TP-3000 Thermal Printer/Plotter offers electromechanical design simplicity using non-impact techniques. It is a compact device intended for use in military environments.

The unit features a solid-state, multiple junction print head. Since there are no moving parts associated with the print head, the life expectancy of the head approaches the service life of the printer.

ASCII coded characters (64 standard; 128 optional) are generated in a 10 x 7 dot matrix pattern exhibiting extremely high resolution and definition. The standard TP-3000 is a 10 character per inch 80-column printer which operates at a print speed greater than 750 lines per minute. For greater density, the Miltope TP-3000 features a dual format 80/132 column capability. By means of a selector switch on the control panel, the printout is converted from the normal 80-column 10 character per inch format to a compressed 132-column, 17-character per inch format.

The inherent versatility of the TP-3000 is achieved through micro-processor control of the print head and paper feed. This feature provides the user with a variety of character fonts as well as high resolution full dot line. The 132 column printer with the graphics mode can output up to 2000 dots per line under user software control.

Printed copy is output through a paper exit slot at the front of the unit. The TP-3000 also provides for its own internal paper supply storage. The output paper handlers provide for continuous paper takeup and may be mounted directly on top of the standard TP-3000 cabinet. An optional paper stacker is available.

Printer electronics include a built-in test capability to allow the printer to exercise and test all logic functions "off-line". All of the electronics required for complete functioning of the printer are packaged on two printed circuit modules utilizing intergrated circuit and microprocessor technology.

A disadvantage is that NCR T1351 thermal print paper rather than ordinary paper is required. This limitation may be of concern for the intended operational environment.

## 6.3 Operating System Comparison

With the MODCOMP Classic II/75 and MIL VAX I computers being similar with respect to computational capability and I/O utilization, the operating system becomes the next area of investigation to compare VAX capability with the Classic II/75. How the operating system schedules and loads various tasks at different priorities, balances demands for memory, CPU and I/O resources can affect the relative performance of two systems after the hardware has been considered.

### 6.3.1 Memory Management

VAX VMS uses virtual memory to support large numbers of tasks which may in themselves be large. MODCOMP's MAX IV operating system also uses virtual memory to support tasks, but is much more limited in that tasks can not be larger than 128 KB for instruction space and 128 KB for operand space. MAX IV uses a 512 byte page of real memory and can assign it as a task requires it.

Thus task memory grows as required up to a maximum of 128 KB each of instruction memory and operand memory. Pages may come in any order from anywhere in the free page area of real memory. MAX IV does not release pages of real memory in order to bring in new pages. Once a page has been loaded from a task image file, it remains in real memory until the task terminates, the programmer codes a release message or an overlay is brought in. Since the maximum program size is fixed, there is a burden and hence additional cost in software development and maintenance to make use of memory management in a manual manner via programmed release of memory, overlays, etc. Tasks can load their entire real memory at the start of execution and this means that, for equal priority tasks, memory is consumed inefficiently since pages which will not be referred to again or will be used infrequently are generally resident until task termination. The VAX VMS would have paged out such pages to make room for other tasks while generally allowing tasks to execute.

The VAX VMS granular unit of memory assignable is the "page" and is permanently fixed at 512 bytes. When a program is initiated or needs more memory, pages are assigned in increments. Such pages of real memory are not contiguous and may come in any order from anywhere in free real memory available for executable code and data. A task may use up to 2 billion bytes (4 billion if only one task is present) of virtual memory with real memory required to support it being much, much less. Only the most currently loaded pages are in real memory. As new pages of virtual memory are referenced and found not to be in real memory (termed a "page fault") the new pages are brought in from the image file or if a previously swapped out page is required, it is re-paged back in from the paging file to real memory. Should it be necessary to make room for the new or returning page, the

oldest loaded resident pages are moved out. Depending on how many user tasks are present and how large real memory is, the actual amount of real memory assigned to support a user's virtual address space will vary. This, in turn, affects performance of tasks.

The collection of pages in real memory assigned to a task is called the "working set". Working sets fluctuate according to the number of active tasks and their characteristics.

Tasks under MAX IV can reference more than the maximum 128K operand space by use of the direct extended addressing available. Programmer control is required in contrast to the VAX VMS where the system manages memory transparently.

Unlike MAX IV, VAX VMS can balance the working set size assigned to each task, in order to obtain maximum efficiency of real memory (defined as permitting the maximum number of tasks to be resident). It may take pages away from one task's working set and give to another which requires additional real memory or to make room for yet another task. MAX IV must maintain the currently assigned real memory. Balancing of working sets under VMS is accomplished through parameters which govern the minimum working set size a task must have, the normal upper limit, and a final upper limit to which a task may grow if there is ample free pages available and temporary borrowing above its normal limit can be permitted. When another task must be activated, VMS will recall borrowed pages and if necessary reduce working sets down below the normal upper limit.

MAX IV does not reduce the working sets it has built up for each task. When space is required for a higher priority task, a lower one is rolled out if necessary to obtain memory. This can lead to more page I/O as program swapping will increase more than with a VAX.

At times during their execution, tasks may perform I/O or be found to be of a lower priority than a newly arriving or re-awakened task. Under MAX IV, a lower priority task(s) in real memory will be entirely swapped out (called roll out) to a swap file. More than one lower priority task may be swapped in order to accumulate sufficient memory for the new or re-awakened task which can then be loaded. VMS would attempt to reduce working set sizes and perform other system chores to obtain memory and if then necessary, will swap out a lower priority task. Every attempt to avoid swapping is made before finally resorting to it. This reduces disk I/O substantially compared to that which might occur in a MAX IV system with tasks being completely rolled out if their memory is required.

### 6.3.2 Fine Tuning

VAX VMS has an extensive set of system performance parameters compared to the MAX IV. These govern intial parameters for real memory use, virtual memory use, task working set sizes, time quanta, and automatic increments to certain parameters used when VMS must adjust the system performance dynamically. Additionally, certain parameters can be operator set while on-line to fine tune the system as it operates, in contrast to setting all parameters at system generation time only. MAX IV does not have such an extensive set of parameters and therefore lacks the ability to fine tune the system as it functions.

### 6.3.3 VMS Security Features

VMS Version 4.0 currently being released has several useful security features not found in MAX IV. All relate to passwords. First, one may have the system present five random passwords which are easily remembered since they are "pronounceable". The user need not use something which relates uniquely to him and could be guessed (e.g., wife's maiden name). The user chooses one

of the five and it is "installed". After pre-set time periods, the system will require passwords be changed and the previous password is prevented from being re-used as the new password. If selected, two passwords can be required, one from each of two persons before access to the system is permitted. Of course this depends on the two persons not revealing their passwords to each other mutually.

Password grabber programs are prohibited by use of the break key before signing on. A password grabber program typically operates as follows: A user develops a program to simulate the log-on process. He executes it and leaves the terminal (with the program still running and presenting a screen typical of an available system). A new user comes to the terminal and signs on. The program makes a copy of the password used and then either stops (the new user just retries log-on thinking sign-on only failed) or it passes the data to the operating system (to finish log-on) and it disappears. Use of the break key in the log-on process will disable such programs before they execute the password grab.

6.3.4 Miscellaneous VMS 4.0 Features

Other features provided in VMS 4.0 will be use of file names up to 39 characters in length, ability to define terminal keyboard keys to be often used phrases or commands, use of multiple windows by software, and a single word response to common control-character key inputs (e.g., control-C meaning cancel, control-Y meaning interrupt will be displayed as "CANCEL" or "INTERRUPT" in reverse video). These features make the VMS more user friendly. DEC VMS 4.0 publications sould be referenced for further detail on these and other new features which may be of interest.

## 6.4 Software

The software is described in detail in Section 5 of this report. It is summarized in Table 5-1. The MIL VAX I implementation supports only one active satellite, as compared with the Classic II/75 implementation. In the two satellite configuration, a substantial number of software modules are duplicated to support the second satellite. Table 5-1 summarizes the unique software required to support a single satellite. The impact of the elimination of duplicated modules in the MIL VAX I system is a reduction in the primary memory used to implement the one satellite configuration. Section 6.5.1 discusses memory utilization in greater detail.

## 6.5 Memory

### 6.5.1 Primary Memory

Primary memory will have the VAX/VMS operating system, common data area, the SDCS executive module, and the telemetry/beacon aquisition module permanently resident. As Table 6-4 shows, this requires 725KB of real memory.

All dynamically loaded tasks added together would consume approximately another 1600KB. With four megabytes of memory it is possible to make some additional number (up to all tasks if desired) memory resident to improve response time. As well, there would be little need for VAX/VMS to perform paging or swapping on these tasks as 1.6 MB would still remain free. Paging would be performed only for initial loading, and both paging and swapping used to make real memory serve more task memory requirements would be unnecessary. Overlays would still be loaded as called.

Table 6-4. Memory Usage - MIL VAX

| MEMORY USER | MEMORY (BYTES) 1 SATELLITE |
|---|---|
| PERMANENTLY RESIDENT: | |
| OPERATING SYSTEM | 500K |
| FORTRAN RUNTIME Library | 30K |
| COMMON | 70K |
| SRE | 25K |
| TELEMETRY ACQUISITION | 70K |
| BEACON ACQUISITION | 30K |
| SUBTOTAL | 725K |
| TEMPORARY RESIDENT: | |
| TASKS | 1,593K |
| OVERLAYS | 1,407K |
| SUBTOTAL | 3,000K |
| TOTAL ALL SOFTWARE | 3,725K |
| PHYSICAL MEMORY AVAILABLE | 4,000K |
| REMAINING MEMORY (IF ALL S/W IS RESIDENT) FOR EXPANSION | 275K |
| REMAINING MEMORY (FOR DYNAMIC ALLOC. OF TEMP. RES. TASKS AND EXPANSION) | 1,682K |

However, there is sufficie·t memory (3275 KB) to hold the 3000 KB of temporarily resident code, and make the entire system memory resident for the fastest response time for any function. To do this, all overlays would have to be converted to subroutines and all calls for overlays converted to subroutine calls. It may be more in line with reality to make only some additional tasks and overlays memory resident and leave less frequently used modules as dynamic loading modules.

This analysis has not assumed that any tasks/overlays are made memory resident other than those so specified for the MODCOMP system. System engineering and integration efforts as well as experience with the converted system will determine if it is beneficial to convert further tasks to memory residency.

6.5.2 Disk Storage

Two Miltope disk storage units of 134 MB each are provided. VAX/VMS may utilize two disk drives. One drive will primarily contain system software and the second will contain the dynamic paging file, where applicable. Pages will be temporarily stored in the paging file while removed from real memory. Application files will be spread across both disks with application programs and the most active files placed on the system disk.

File sizes on disk remain the same as for MODCOMP, except that VAX/VMS requires 18 MB on the system disk and 9 MB on both the paging disks. VAX/VMS, FORTRAN and other software supplied by DEC, together with the paging/swapping areas can consume 50-70 MB of disk.

Figure 6-3 shows a typical disk allocation.

6.6 Performance Estimates

6.6.1 CPU Utilization

The *MIL-VAX I is rated at 1 MIPS (million of instructions* per second) as a 32-bit machine while the MODCOMP Classic II is rated at 0.96 MIPS, but is only a 16-bit machine. Therefore, it is logical to expect that, although closely rated in raw numbers for MIPS, there is a substantial difference. The MIL-VAX I might be really 1.2 MIPS or more <u>relative</u> to the MODCOMP. To measure the difference, one would have to execute a benchmark on both systems, an opportunity unavailable to CSC. CSC has assumed that MODCOMP can safely be represented as a 0.96 MIPS machine in estimating the performance differences. The MIL VAX performance has been used as 1.20 MIPS (equivalent 16-bit instructions).

Performance estimates were developed by creating a model of the processing load and the processing power of the given computer system (MODCOMP, MIL VAX I and DEC VAX 11/780). The major steps to this effort were:

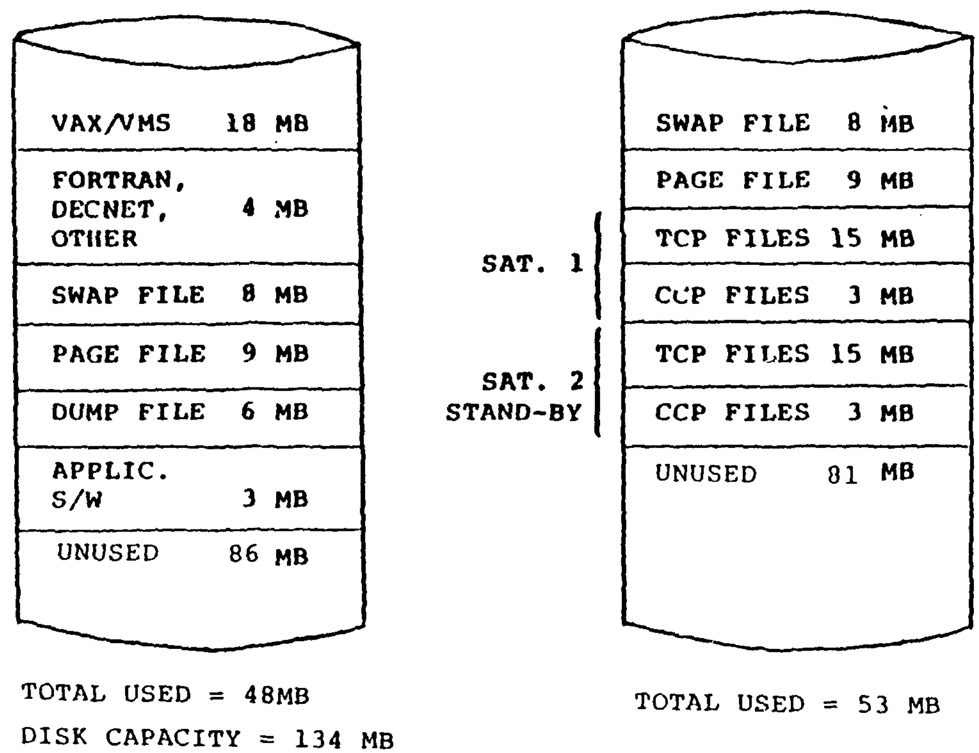
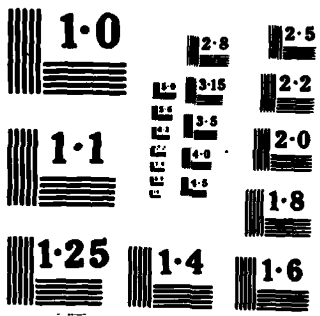



Figure 6-3. Typical Disk Allocation - One Satellite

AD A161 158 SCCE REHOSTING FEASIBILITY ASSESSMENT(U) COMPUTER SCIENCES CORP FALLS CHURCH VA SYSTEMS DIV S DRESSLER ET AL. 31 OCT 85 DCA100-81-C-0044

UNCLASSIFIED F/G 17/2 NL

END
DATE
FILMED
12-85
DTIC


1·0
2·8
2·5
3·15
2·2
3·5
2·0
4·0
1·1
4·5
1·8
1·25
1·4
1·6

a. Analyze representative modules of TCP and CCP. As shown in Appendix I, each listed module was examined to determine the number of instructions executed for normal paths and abnormal condition paths. Number of instructions for paths are weighted by the expected probability of their occurrence.

b. Each module was assigned a frequency of executions per second.

c. Number of instructions was then multiplied by probability of execution and by the frequency of execution to yield the expected load presented to the computer system.

d. The load of each module is summed to obtain the total average load (or peak load) depending on which modules were included for average (or peak) load cases.

It is to be noted that the process above consists of spreading the computational load of each module over the period between executions for that module. While this determines whether the system is overloaded or not, in reality, the system will execute the highest priority modules first and then allocate remaining capacity to lower priority modules. The VMS operating system will continue to dispatch modules as they arrive for execution using up to 100% of the system if necessary. But over time, the system will average a utilization near that predicted since there will also be "dead periods" of little or no activity.

Operating system overhead is assumed to be 25% of the application modules load. This figure was arrived at by watching the system manager console on a DEC VAX-11/780 for a number of hours and sampling the percent of time spent in user mode and the system modes (e.g., kernel, executive).

Since the MIL VAX I and DEC VAX 11/780 are so closely rated in MIPS (1.20 vs 1.27) and are 32-bit machines of the same general architecture using DEC VAX/VMS, the analysis of the MIL VAX I can be applied to the DEC VAX 11/780 in a one satellite configuration.

CSC has had the opportunity to examine a report of SCCE operator activities performed over a long period of time. Many of the activities requiring the use of software modules included in the analysis were performed once or twice a day, or less frequently, such as weekly, monthly, etc. The analysis CSC has performed assumes that many of these activities are being performed relatively simultaneously. Therefore, CSC believes that the system will actually be less loaded than presented here. In fact it may be that for hours, only telemetry/beacon acquisition, processing, archiving and report generation will be the only events occurring.

CSC has analyzed three conditions: average, playback and busy minute, for both 1 and 2 satellites. The average condition represents normal conditions. The playback condition places one satellite telemetry data stream in a 4 Kbps playback mode. The busy minute places all real time functions at their normal rate and adds to this processing load, the processing of data span analysis. These conditions are defined in greater detail in Appendix I, para 2.5.

The results of CSC's processor utilization analysis are presented in Table 6-5. For comparative purposes, results are shown for the MODCOMP, MIL VAX I and DEC VAX 11/780 systems.

A functional breakdown of average processor utilization appears in Table 6-6. Although this breakdown is specifically for the MODCOMP Classic II/75 computer supporting only one satellite, it is representative of the functional breakdown for average processor utilization for the MIL VAX I or DEC VAX 11/780, supporting one or two satellites.

Table 6-5. Processor Utilization

| COMPUTER | PROCESSING | | 1 SATELLITE | | | 2 SATELLITES | | |
|---|---|---|---|---|---|---|---|---|
| | Rate[3] (MIPs) | OVHD | Avg | PLBK[1] | Bsy Min | Avg | PLBK[2] | Bsy Min |
| MODCOMP | .96 | .25 | .25 | .48 | .33 | .50 | .72 | .66 |
| MILVAX I | 1.20 | .25 | .20 | .38 | .27 | .40 | .57 | .53 |
| VAX 11/780 | 1.27 | .25 | .19 | .36 | .25 | .38 | .54 | .50 |

1 Single satellite in 4 Kbps playback mode.

2 One satellite in 4 Kbps playback mode, one satellite in 1 Kbps normal mode.

3 Equivalent 16-bit instructions.

Table 6-6. Functional Breakdown of Average Processor Utilization MODCOMP-Baseline .96 MIPS-One Satellite

| CATEGORY | FUNCTION | UTILIZATION | PERCENT |
|---|---|---|---|
| 1 | TLM Acquisition Process | .056 | 28 |
| 2 | CMD, Gen, Xmt | .018 | 9 |
| 3 | CCP | .053 | 27 |
| 4 | Data Span Analysis | .002 | 1 |
| 5 | Display Generator | .060 | 30 |
| 6 | Intersite Data Transfer | .0002 | |
| 7 | O.S. Interface | .002 | |
| 8 | Data Span Report Generator | .006 | 3 |
| 9 | Support Systems | .00001 | - |
| | O.S. Overhead (.25) | .049 | |
| | TOTAL | .246 | 100 |

### 6.6.2 Estimated I/O Utilization

#### 6.6.2.1 Channel Utilization

Two UNIBUSs are used in the SDCS-MIL VAX I configuration. UNIBUS #1 is utilized 2.7% of the time and UNIBUS #2 is utilized 10.7% of the time (peak instantaneous loading). Refer to Table 6-7, MIL VAX I I/O Utilization.

Utilization estimates for a peak period loading were developed as follows: Each device which is closely related to the telemetry rate is assumed to operate at that rate (128 words per second). Such devices are the TPUs, TCG (time code generator), and TCT (time code translator), etc. Other devices such as the printer-plotter, tape drive, and RS-232-C lines are assumed to be operating at 100% of the transfer rate as would happen during the transfer of records at any given moment (of course, this is a burst rate which does not continue forever). The estimate for a given UNIBUS is the sum of these transfer rates. Percentage utilization is determined by dividing the total words transferred per second by 750K words per second, which is the maximum per second rate that a UNIBUS can handle.

Because the peak instantaneous utilization is sufficiently low, the average utilization, which would be even lower, has not been calculated.

#### 6.6.2.2 Device Utilization

Disk Utilization has been determined as follows:

Average accesses per second for a single satellite, mostly from the TLMPR1 load module, are estimated at 3.6 accesses/sec. Disk accesses are assumed to have an average access time of 30 ms for either the MODCOMP or MIL VAX (or DEC VAX) system.

On the MODCOMP system, all system files are on a separate system disk and all data files are on a separate data disk. The MIL VAX I system for the SDCS has system files distributed on both disks, along with data files. Thus on the MIL VAX system a

Table 6-7. MIL VAX I I/O Utilization - One Satellite
(Word Size = 16 bits)

| | |
|---|---|
| UNIBUS #1 (750K words/sec max.) | |
| TPU #1 | 128 words/sec |
| TPU #3 | 128 words/sec |
| D/A CONVERTER | 128 words/sec |
| PRINTER/PLOTTER | 10,000 words/sec |
| 8 LINES (RS232C, 9600 bps) | 9,600 words/sec |
| | ------------ |
| | 19,984 words/sec |
| Utilization (Peak Instantaneous) | 2.7% |
| UNIBUS #2 (750K words/sec max.) | |
| PRINTER/PLOTTER | 10,000 words/sec |
| SCT-TLM | 128 words/sec |
| TCT | 128 words/sec |
| TCG | 128 words/sec |
| SIG. MUX. | 128 words/sec |
| TAPE DRIVE | 60,000 words/sec |
| 8 LINES (RS232C, 9600 bps) | 9,600 words/sec |
| | ------------ |
| | 80,112 words/sec |
| Utilization (Peak Instantaneous) | 10.7% |

system overhead (estimated at 10%) is added to the 3.6 accesses/sec resulting in 4 accesses/sec. The MIL VAX I spreads this activity over two disks. In the worst case, peak activity will be on a single disk.

Thus for the MODCOMP the utilization is calculated as:

$U_D$ = 3.6 accesses/sec x 30ms/access = .11.

For the MIL VAX I, disk utilization is calculated

$U_D$ = 4.0 accesses/sec x 30ms/access = .12

For the MIL VAX I based SDCS system, operating at a normal 1 Kbps telemetry data rate, this provides an large margin of performance. In the playback mode, with telemetry data at a 4 Kbps rate, this implies a disk utilization of .48, providing adequate margin.

CRT activity is dependent on interactive scenarios. In a typical sequence of command generation, CSC has estimated the average CRT activity level to be 8-10 accesses per minute. This activity level is easily supported by a single CRT device. Printer/ploter activity is also tied to operator interaction. A single printer/plotter will support all of the SCCE requirements for a single satellite. A typical report run every 1-2 hours takes 3 minutes. Single graphics outputs take 5 minutes to plot. Printer/plotter utilization is estimated at 30-40%, in support of a single satellite. A second printer/plotter will be required to support two satellites.

### 6.6.3 Performance Assessment

This configuration supports only one active satellite. Peak processor utilization is estimated at 38%. I/O channel instantaneous utilization is estimated at 10.7%. Average disk utilization is estimated at 12%. Under playback conditions, disk

utilization is 48%. Allowing for substantial errors in CSC's analysis, it appears that adequate margins exists in processor performance and I/O channel performance. Disk utilization may be too high under playback conditions. Further analysis and verification using the MODCOMP system are recommended.

## 6.7 Hardware Cost

Table 6-8 presents the cost of a MIL VAX I computer system. This is a cost for an order placed before June 18, 1985, with delivery for 1988 time frame. Hardware cost is $731,020. With typical handling charge and profit (total 14%) added, the cost to the government is estimated at $833,363.

Table 6-8. MIL VAX I Costs

| Quantity | Model # | Description | Cost |
|---|---|---|---|
| 1 | M4-3000 | MIL VAX I consisting of:<br><br>o Data Path<br>o Memory Interface<br>o Control Store<br>o Maintenance Control<br>o UNIBUS Adapter<br>o Memory Controller<br>o UNIBUS Exerciser/Terminator<br>o Two 512KB Semiconductor Array Memory<br>o 8-Channel Serial Multiplexer<br>o Power Supply<br>o AC Power Cable<br>o DC Power Cable<br>o Console Cable<br>UNIBUS Cable | |
| 6 | M4-2900 | 512KB Semiconductor Array Memory | |
| 1 | M4-8340 | Floating Point Processor | |
| 1 | M4-8370 | Diagnostic Data Module | |
| 1 | M4-8360 | Second UNIBUS | |
| 7 | M2-DR11-C | General Purpose Digital Interface | |
| 1 | M2-4501 | Line Printer Controller | |
| 1 | M2-6003-C | I/O Expansion Unit | |
| 1 | M2-6202 | UNIBUS Repeater | |
| 1 | M2-DZ11-A | 8-Channel Serial Multiplexer<br>CMI Disk Controller | |
| | | VENDOR PRICE | $533,500 |

TABLE 6-8. MIL VAX I Costs (Cont'd)

| Quantity | Model # | Description | Cost |
|---|---|---|---|
| | | Miltope Equipment (MIL-SPEC) | |
| | | TP-1161 Tape Drive and Controller | $ 68,600 |
| | | RDS-160 Disk Subsystem (2 disks) | 76,000 |
| | | TP-3000 Printer/Plotter* | 25,300 |
| | | Software Licenses (VMS, FORTRAN, DECNET) | $ 27,620 |
| | | Subtotal | $731,020 |
| | | Handling Charge & Profit (14%) | $102,343 |
| | | TOTAL COST | $833,363 |

*Hi-temperature thermal paper costs $150/3000 sheets

## 7.0 DSCSOC - DEC VAX SYSTEM

### 7.1 Configuration

The DSCSOC architecture will be the same as that shown in Figure 4-1 which is the current SCCE architecture for two satellites. The primary change is to substitute a Digital Equipment Corporation (DEC) VAX 11/780 for the current MODCOMP CLASSIC II/75. Computer interface controllers to TCS and ETI subsystems are also changed to be VAX compatible. Figure 7-1 shows the VAX 11/780 configuration. Table 7-1 lists the major peripheral devices.

### 7.2 DEC VAX-11/780

#### 7.2.1 Central Processor

Two hundred forty-eight basic instructions are included in the VAX-11/780, allowing arithmetic operations, bit/byte string manipulation, jump, I/O, logical operations, etc. Certain instruction are provided to support higher-order language constructs such as loops, etc. Full 32-bit arithmetic operations and 32-bit addressing are supported. Data can be addressed in any one of nine different methods such as direct addresses, indexed etc. The VAX 11/780 has a processing rate of 1.06 MIPS (32-bit instructions). Instruction execution is rated at 1.27 MIPS (equivalent 16-bit instructions) compared to 1.20 MIPS for the MIL VAX I and 0.96 MIPS (16-bit instructions) for the MODCOMP Classic II/75.

A floating point accelerator to speed up floating point calculations is available as is a customer usable "writeable control store" for customer instruction. The latter could be employed to optimize and speed-up instructions which are often used or would otherwise require several VAX-11/780 machine instructions.

An address translation buffer to speed up instruction fetch/execution is also employed, as described for the MIL VAX I processor in paragraph 6.2.2.

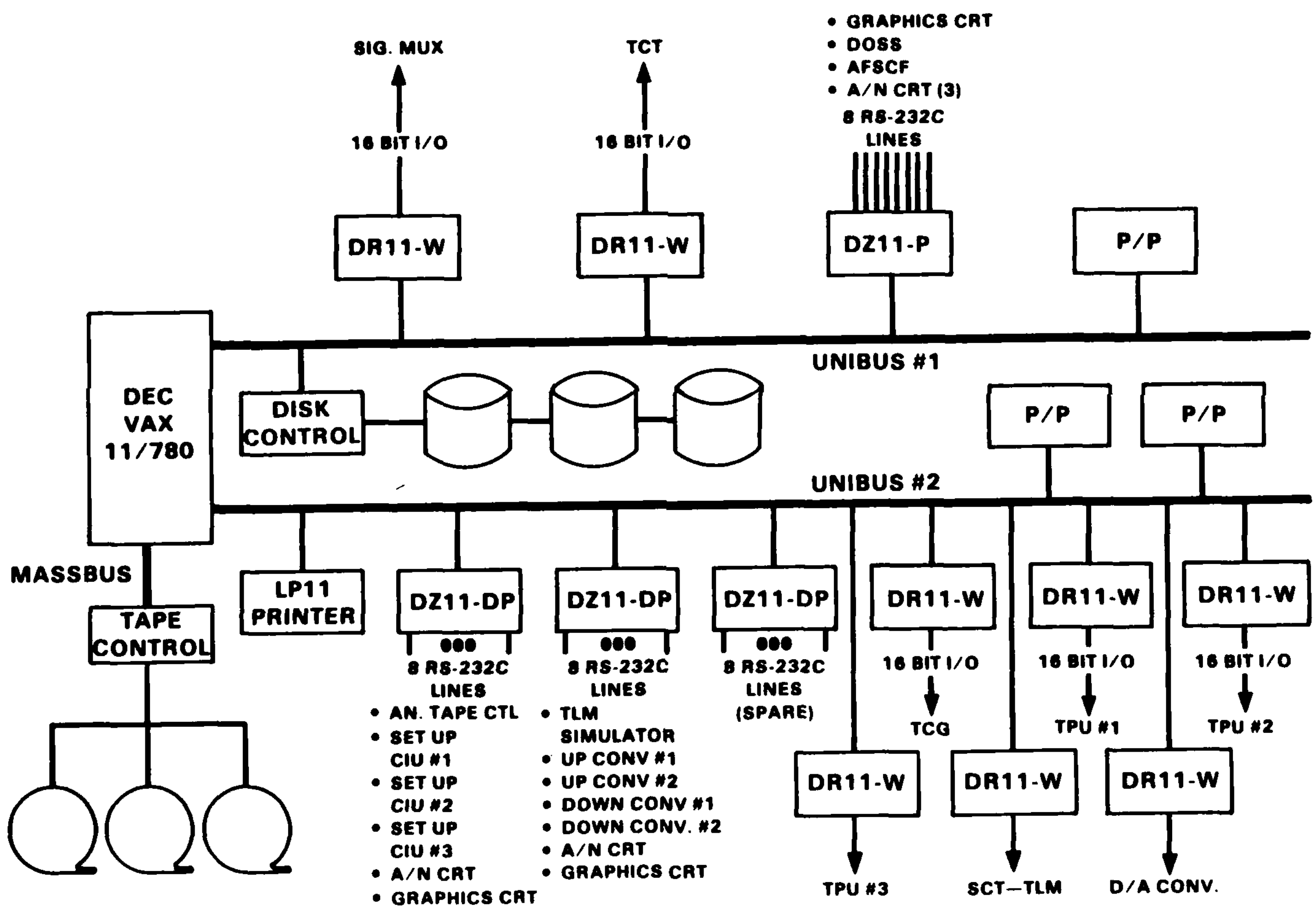



Figure 7-1. DSCSOC VAX 11/780 Configuration

TP No. 065-16975-A-A

Table 7-1. DSCSOC CD/CPS Peripherals

| QUANTITY | DESCRIPTION |
|---|---|
| 3 | Magnetic Disk Drives (121 MB each) |
| 3 | Magnetic Tape Drives |
| 1 | Line Printer (600 lpm) |
| 3 | Printer/Plotter |
| 5 | AN/CRTs |
| 3 | Graphic CRTs |
| 3 | Programmable Function Keyboards |

### 7.2.2 Primary Memory

The VAX 11/780 supports up to 32 MB of semiconductor memory. For the DSCSOC, four MB minimum of memory will be required. However, VAX-VMS can support up to eight megabytes. Thus, should it be necessary to increase memory to improve performance (especially to allow more load modules to be resident for faster response time and to reduce paging/swapping), one can use up to eight MB. An initial use of six megabytes may be beneficial to decrease labor costs of optimizing SCCE code conversion to fit a lesser memory, such as the four MB limit.

The semiconductor memory employs an error correcting code scheme to detect errors and perform single bit error corrections. Using the cache memory in conjunction with primary memory, the cycle time is 290 nanoseconds compared to the MODCOMP cycle time of 250 nanoseconds. The true 32-bit architecture of the VAX 11/780 compared to the 16-bit architecture of the MODCOMP overcomes MODCOMP's apparent speed advantage.

Battery backup for the MOS semiconductor memory is available as an option and has been selected for the DSCSOC. It is capable of supporting two megabytes for 15-20 minutes of power outage.

7.2.3 I/O Subsystem

The VAX 11/780 uses two types of busses for I/O. The high speed bus (2.0 MB/second) is called a MASSBUS (up to four allowed), and supports high speed devices such as magnetic tapes. One is used in the DSCSOC to support the three tape drives.

Two low speed (1.5 MB/second) UNIBUSSES will be used to support dual ported magnetic disks (3), and all other interfaces such as CRTs, telemetry and earth terminal interfaces, printers, etc.

7.2.3.1 Parallel I/O Interface

The 16-bit parallel I/O interface is the DR-11W controller. It is generally that described in paragraph 6.2.4.1 for the MIL VAX I. Signal leads are the same. Table 6-3 can be used to compare MIL VAX I/VAX-11/780 and MODCOMP signals on the interface to the user's device. Conversion engineering will probably be necessary to interface the DR-11W to the telemetry subsystem equipment which originally was designed to interface to a MODCOMP parallel I/O controller.

7.2.3.2 RS232C Asynchonous Line Controller

The DZ11-DP provides the required RS232C 9600 bps communications lines required. Minimal conversion engineering should be necessary as DEC and MODCOMP both claim to use the EIA RS232C standard which governs voltage levels, waveforms, timing, etc.

### 7.2.4 Peripheral Storage Devices

#### 7.2.4.1 Magnetic Disk Drives

Three RA80 disk drives having 121 MB formatted capacity will be used for the configuration. These drives have an average access time of 30 ms. and a peak transfer rate of about 1.2 megabits per second. Winchester technology is the basis of construction. Three drives can be mounted in one cabinet.

Each drive has a dual port capability as a standard feature. Hence either UNIBUS can be used to access a given drive. This feature is employed in the DSCSOC configuration.

Seventeen thousand spare sectors are available for dynamic defect reallocation. Reliability of the drive is further enhanced by a 170-bit error correction code.

#### 7.2.4.2 Magnetic Tape Drives

Three TEU77 magnetic tape drives will be used in the DSCSOC configuration for on-line archival as well as disk copy/restore operations, etc. Characteristics of these tape drives are: one-half inch width, IBM compatible recording, 800/1600 bpi, 125 ips and 70 second retrieval time. One controller will be used to control these three tape transports (maximum is four transports).

### 7.2.5 Other I/O Devices

#### 7.2.5.1 Printer

An LP11 600 lines per minute band printer can be used to satisfy DSCSOC printer requirements. This printer has an 96 ASCII character set, 132 columns 6/8 lines/inch vertical spacing, self-test capability, and uses up to six-part pin feed continuous fan-folded paper.

7.2.5.2 Alphanumeric CRT Devices

VT100's which are currently used in the SCCE, are considered to be used in the DSCSOC.

7.2.5.3 Graphics CRT Devices

Tektronix 4014-11 Graphics CRTs which are currently used in the SCCE, are considered to be used in the DSCSOC DEC VAX 11/780 system.

7.2.5.4 Versatec C-TEX-5 Switch

The C-TEX-5 data switch is expected to be used to coordinate input to the Versatec V80 printer/plotter from either a Tektronix 4014 graphic CRT or the computer system. The interface to the UNIBUS from the C-TEX-5 would be supplied by Versatec.

7.2.5.5 Printer/Plotter

The printer/plotter will be a Versatec V80 unit as currently used in the SCCE configuration.

7.3 Operating System

The VAX-VMS operating system as described in paragraph 6.3 and used on the MIL VAX I will be used on the VAX-11/780.

7.4 Software

The software is described in detail in Section 5 of this report, and is essentially the same as that used on the SDCS MIL VAX I system. Refer to Table 5-1 for a summary.

7.5 Memory

7.5.1 Primary Memory

Primary memory will have the VAX/VMS operating system, common data area, the SDCS executive module and the telemetry/beacon acquisition module permanently resident. As Table 7-2 shows, this requires 915K bytes of memory.

Table 7-2

Memory Usage - DEC VAX 11/780

| Memory User | Memory (Bytes) | |
|---|---|---|
| | 1 Satellite | 2 Satellites |
| Permanently Resident: | | |
| Operating System | 500K | 500K |
| FORTRAN Runtime Library | 30K | 30K |
| Common | 70K | 140K |
| SRE | 25K | 25K |
| Telemetry Acquisition | 70K | 140K |
| Beacon Acquisition | 30K | 70K |
| SUBTOTAL | 725K | 915K |
| Temporarily Resident | | |
| Tasks | 1,593K | 2,688K |
| Overlays | 1,407K | 2,397K |
| SUBTOTAL | 3,000K | 5,085K |
| Total All Software | 3,725K | 5,980K |
| Physical Memory Available | 4,000K | 6,000K |
| Remaining Memory (if all S/W resident) For Expansion | 275K | 20K |
| Remaining Memory for Dynamic Alloc. of Temp. Res. Tasks and Expansion | 3,275K | 5,085K |

All dynamically loaded tasks and overlays added together would consume another 5000K bytes (approximately). With six megabytes of memory it is possible to make some additional number of tasks (up to all tasks if desired) memory resident to increase response time. Under this condition, there would be no need for VAX/VMS to perform paging or swapping on these tasks. Paging would be performed only for initial loading.

A lower risk approach would permanently load all tasks into primary memory, but would dynamically load overlays, as required.

This analysis has not assumed that any tasks/overlays are made memory resident other than those so specified for the MODCOMP system. System engineering and integration efforts as well as experience with the converted system will determine if it is beneficial to convert further tasks to memory residency.

### 7.5.2 Disk Storage

Three RA 80 121 MB Winchester disk drives are provided in the DEC VAX 11/780 system. VAX/VMS uses two disk drives in order to function efficiently (primarily by spreading accesses). Allocation of the VAX/VMS and other system software, applications software, and files as well as paging/swapping files will be generally as given in paragraph 6.5.2 for the MIL VAX I. Files, however, will be increased to account for two satellites.

The third disk is allocated as spare. However, should performance needs in the future demand it, the third disk can be used for files, paging/swapping, etc. On failure of a disk, the system can be reconfigured to use the remaining two disks.

Figure 7-2 shows a typical disk allocation for the two satellite configuration.

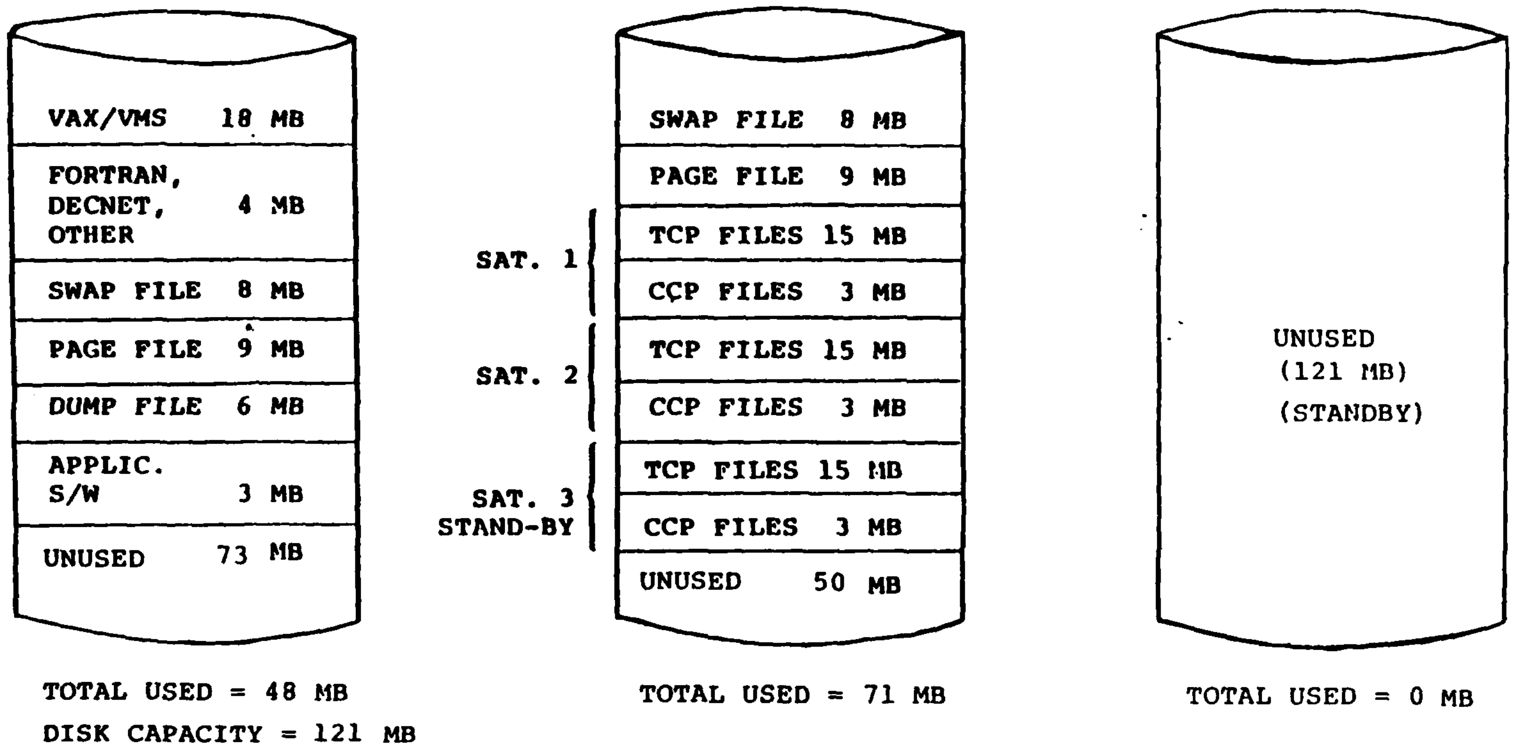



Figure 7-2. Typical Disk Allocation - Two Satellite

## 7.6 Performance Estimates

### 7.6.1 CPU Utilization

The CPU utilization analysis was performed for the DEC VAX 11/780 exactly as described in paragraph 6.6.1 for the MIL VAX I. Modules included were expanded to account for processing for a second satellite. The reader should refer again to that paragraph.

The results of CSC's processor utilization analysis are presented in Table 7-3 (identical to Table 6-5). The conditions of the analysis are defined in Appendix I, paragraph 2.5.

### 7.6.2 Estimated I/O Utilization

#### 7.6.2.1 Peak Instantaneous Channel Utilization

The MASSBUS used has a utilization of 15.4%. Two UNIBUSSES are used in the SDCS-MIL VAX I configuration. UNIBUS #1 has a maximum instantaneous utilization of 84.8% (supporting 3 disks simultaneously), and UNIBUS #2 has a maximum instantaneous utilization of 17.5%. Refer to Table 7-4, DEC VAX 11/780 I/O Utilization.

Utilization estimates for a peak period loading were developed as follows: Each device which is closely related to the telemetry rate is assumed to operate at that rate (128 words per second). Such devices are the TPUs, TCG (time code generator) and TCT (time code translator), etc. Other devices such as the printer-plotter, tape drive and RS-232-C lines are assumed to be operating at 100% of the transfer rate as would happen during the transfer of records at any given moment (of course, this is a burst rate which does not continue forever). The estimate for a given UNIBUS is the sum of these transfer rates. Percentage utilization is determined by dividing the total words transferred per second by 750K words per second which is the maximum per second rate that a UNIBUS can handle.

Table 7-3. Processor Utilization

| COMPUTER | PROCESSING | | 1 SATELLITE | | | 2 SATELLITES | | |
|---|---|---|---|---|---|---|---|---|
| | Rate[3] (MIPs) | OVHD | Avg | PLBK[1] | Bsy Min | Avg | PLBK[2] | Bsy Min |
| MODCOMP | .96 | .25 | .25 | .48 | .33 | .50 | .72 | .66 |
| MILVAX I | 1.2 | .25 | .20 | .38 | .27 | .40 | .55 | .53 |
| VAX 11/780 | 1.27 | .25 | .19 | .36 | .25 | .38 | .54 | .50 |

[1] Single satellite in 4 Kbps playback mode.

[2] One satellite in 4 Kbps playback mode, one satellite in 1 Kbps normal mode.

[3] Equivalent 16-bit instructions.

Table 7-4. DEC VAX-11/780 Channel Utilization
(Word size = 16 bits)

| Bus/Transfer Rate Device Load | Instantaneous Peak Bus Load | Average Peak Bus Load 1 Sat | Average Peak Bus Load 2 Sat |
|---|---|---|---|
| MASSBUS/1000 KW/S | | | |
| Tape Drives | 100 KW/S | | |
| Utilization | .10 | <.10 | <.10 |
| UNIBUS #1/750 KW/S | | | |
| 3 RA80 Disks | 600 KW/S | | |
| Printer/Plotter | 26 KW/S | | |
| 8 RS 232C Lines | 10 KW/S | | |
| Total | 636 KW/S | | |
| Utilization | .848 | .359 | .449 |
| UNIBUS #2/750 KW/S | | | |
| 2 Printer/Plotters | 52 KW/S | | |
| Line Printer | 60 KW/S | | |
| 16 RS 232C Lines | 19 KW/S | | |
| Total | 131 KW/S | | |
| Utilization | .175 | <.175 | <.175 |

7.6.2.2 Peak Average Channel Utilization

As shown in Appendix A, 2.2.3, peak average channel utilization, $U_C$, due to disk activity (the primary component of channel utilization)is given by:

$$U_C = \frac{L/T}{R_T} \times U_D$$

where

$U_D$ = disk utilization
L = record length (KW)
T = rotational period (sec)
$R_T$ = transfer rate (KW/S)

For a two-satellite situation,

$U_D$ = 0.6
$R_T$ = 660 KW/S
L = 7.9 KW
T = 16 mS,

$$\text{and } U_C = \frac{\frac{7.9 \text{ KW}}{16 \text{ MS}}}{660 \frac{\text{KW}}{\text{S}}} \times .6 = .449$$

In support of only one satellite,

$U_D$ = .48,

and $U_C$ = .359

7.6.2.3 Device Utilization

Refer to paragraph 6.6.2.2 for the rationale of disk utilization calculations. For the DSCSOC, supporting 2 satellites, both at a normal 1 Kbps data rate:

$U_D$ = .12 x 2 = .24

With one satellite in a 4 Kbps playback mode and one satellite at a normal data rate:

$U_D = (.12 \times 4) + .12 = .60$

CRT activity will be similar to that described in paragraph 6.2.2, though doubled due to the 2 satellites, and using an additional CRT. No difficulty is anticipated with CRT capacity. Printer/plotter activity is doubled over the one satellite case, but the presence of an additional printer/plotter will keep the utilization of each device in the 30% to 40% range.

7.6.3 Performance Assessment

This configuration supports two active satellites. Under playback conditions, CSC has estimated the processor utilization to be 54% (a very comfortable margin). If, due to the potential uncertainty sources listed in Appendix I, paragraph 2.4, CSC has underestimated the processor utilization, then it may be as high as 72%. This would constitute an inadequate margin, and would result in significant degradation of response time if significant enhancements are added. The maximum instantaneous channel rates are well below 100%. The worst-case is on UNIBUS #1 where instantaneous bursts of data may utilize 84.8% of the bus capacity. The average bus utilization, under peak loading conditions, is 45%. This provides adequate assurance that bus loading does not degrade system performance. However, disk utilization under Playback conditions may be as high as 60%. The principal contribution is from the TLMPR1 load module. If, due to the potential uncertainty sources listed in Appendix I, paragraph 2.4, CSC has underestimated the disk utilization, then it may be as high as 80%. To reduce disk utilization, the files for active satellite 1 and 2 should be on separate disks. This would reduce disk utilization to about 50%.

All of the above considerations are subject to the uncertainties of CSC's analysis. Verification of performance under these conditions, using the MODCOMP implementation, is recommended.

## 7.7 Hardware Cost

Table 7-5 presents the costs of a DEC VAX 11/780 computer system. Total cost is $306,441, using GSA price schedule and 18% discount (a typical OEM discount). Adding in a software license cost of $27,620 brings the total to $334,061. A typical general and administrative overhead plus profit of 14% should be applied to give a cost to the government of $380,829.

Table 7-5. DEC VAX-11/780 Configuration Cost

| Quantity | Model Number | Description | Cost |
|---|---|---|---|
| 1 | 780AX-AE | VAX-11/780 (2 MB) | |
| 1 | MS7890-FC | 6MB Memory | |
| 4 | DZ 11-DP | 8 Line Async. Multiplexer | |
| 8 | DR 11-W | General Purpose DMA I/F | |
| 1 | RA 81-EA | 3 456 MB disk drives plus cabinet | |
| 1 | TEU77-FB | 1600/800 Tape Drive and Controller | |
| 2 | TU77-MF | 1600/800 9TRK Tape Drives | |
| 1 | LA120-DA | Console | |
| 1 | F P780-AA | Floating Point Accelerator | |
| 1 | H 7112-A | Battery Back-up | |
| 1 | LP11-EB | 600 LPM Board Printer | |
| 1 | H9652-MF | UNIBUS Expansion Cabinet | |
| 3 | BA 11-KU | 10 1/2 Inch Expander Box | |
| 4 | DD11-DK | Expansion Back Planes for BA11-KU | |
| | | VENDOR PRICE | $306,441 |
| | Software Licenses | | 27,620 |
| | | SUBTOTAL | 334,061 |
| | | G/A plus profit (14%) | 46,768 |
| | | TOTAL | $380,829 |

## 8.0 REHOSTING COSTS AND SCHEDULE

### 8.1 General

This section addresses the costs and schedule to rehost the SCCE software on a MIL VAX I computer system and follows with the additional costs (software needs be converted only once) to use a DEC VAX 11/780 computer in the DSCSOC. Costs and schedule estimates are limited to conversion of software, procurement of hardware, set-up of computer and telemetry simulator, integration and limited acceptance testing as well as documentation (to include the additional documentation describing system hardware/software modifications, etc.)

Six phases are envisioned for conversion:

- o System engineering
- o Software Conversion
- o Interface/Cable Fabrication
- o System integration
- o Acceptance testing
- o Documentation

### 8.2 Rehosting to MIL VAX I

#### 8.2.1 System Engineering

System engineering includes review of SCCE documentation to acquire the necessary basic system knowledge to produce and test a system which will meet the system specifications. Other major elements are VMS operating system parameter value determination, VMS sysgen, specification of operating system modifications required, review and engineering pertaining to computer hardware and software as well as equipment rack/elevation/cabling and

interface system engineering. Specifications for semi-automatic software conversion will be developed. Embedded assembly language will be reviewed to determine if it can be replaced by FORTRAN statements in this faster, more efficient computer environment.

Approximately 25 staff months are required for these system engineering activities.

8.2.2 Software Conversion

Table 8-1 presents a summary of the software conversion effort.

8.2.2.1 Application Software

8.2.2.1.1 FORTRAN Conversion

SCCE FORTRAN modules consist mostly of FORTRAN statements, but with a limited amount of assembly language statements embedded to increase the code efficiency and speed of operation. In some CPCs, INCLUDE statements at the beginning of these modules bring in 50-150 (on the average) FORTRAN statements related to COMMON and to definitions of various data elements. For each FORTRAN module, all its FORTRAN and assembler statements must be converted as necessary one by one, but the code referenced with INCLUDE statements need be converted only once.

As indicated in Section 5.2 of this report, all of the FORTRAN statements in the Modcomp programs may be replaced by the VAX equivalents or copied over directly. For the purpose of estimating software conversion costs, CSC assumes that the following semi-automated method would be used:

A conversion program would be written to process FORTRAN program statements according to the rules in section 5.2 of this report. Statements which the program encounters as matching one of the rules would be converted. Those which partially match

Table 8-1. Software Conversion Estimates Modcomp to MIL VAX [1]

| SOFTWARE DESCRIPTION | FORTRAN | | | ASSEMBLER | | | TOTAL |
|---|---|---|---|---|---|---|---|
| | LoC | SM/KLOC | SM | LoC [1] | SM/KLOC | SM | SM |
| CONVERSION S/W | - | - | 6.0 | - | - | - | 6.0 |
| APPLICATIONS SOFTWARE | | | | | | | |
| TCP | 57,404 | 0.4 | 23.0 | 688 | 5.13 | 3.5 | 26.5 |
| CCP | 29,415 | 0.4 | 11.8 | - | - | - | 11.8 |
| UTILITIES | 17,383 | 0.4 | 7.0 | 3,888 | 5.13 | 19.9 | 26.9 |
| COMMON | 11,000 | 0.2 | 2.2 | - | - | - | 2.2 |
| COMMENTS | 115,780 | 0.1 | 11.6 | 5,000 | .1 | 0.5 | 12.1 |
| UNEXECUTABLE CODE [1] | 11,580 | 0.4 | 4.6 | - | - | - | 4.6 |
| AUX. EXEC. [2] | - | - | - | 26,406 | 10.0 | 264.1 | 264.1 |
| TOTAL (APPLICATIONS) | 242,562 | - | 60.2 | 35,982 | - | 288.0 | 348.2 |
| SYSTEM SOFTWARE | | | | | | | |
| MACROS | - | - | - | 22,400 | 10.0 | 224.0 | 224.0 |
| PROCEDURES | - | - | - | 5,300 | 10.0 | 53.0 | 53.0 |
| TOTAL (SYSTEM) | | | | 27,700 | - | 277.0 | 277.0 |
| TOTAL | 242,562 | - | 66.2 | 63,682 | - | 565.0 | 631.2 |

[1] Format, Data, Specification Statements

[2] May not be required

would be flagged for manual intervention as would any assembler language statements. All others would be copied over as they stand. After the run, the programmer would correct the partially converted (flagged) statements, if any should occur, and update the software library. The embedded assembler language statements would be replaced manually by the FORTRAN CALL statements. A subroutine would be created manually with assembler statements equivalent to those replaced by the CALL statement.

Using this method, the actual conversion plus compilation of all modules (but not including integration) is estimated at 0.4 staff months per 1000 lines of executable code. COMMON statements are estimated at 0.2 staff months per 1000 lines of code. COMMENTS, which must be updated, are estimated at 0.1 staff months per 1000 lines of code. The estimated conversion effort is 66.2 staff months, including 6.0 staff months for the development of the conversion program.

8.2.2.1.2 Assembler Language

Those modules which are done entirely in assembler language should also be analyzed in the system engineering phase of the project to determine if they could be coded in VAX FORTRAN due to the speed of the VAX, it's compiler efficiency, and the purpose of the routine. Where FORTRAN can be used, it should be. Review of documentation on why these were originally done in assembler is necessary for that effort.

For estimating purposes, it is assumed that all the assembler code must be converted manually. The nature of the coding may change due to differences in the MAX IV and VMS operating systems. A figure of 5.13 staff months per 1000 lines of code has been used for the assembler code, exclusive of comments and Auxiliary Executive Routines resulting in 23.4 staff months.

Comments are estimated to take an additional 0.5 staff months. The Auxiliary Executive Routines may not be required. However, they are estimated at 10 staff months per 1000 lines of code. The total conversion of the applications assembler software is estimated at 288.0 staff months.

#### 8.2.2.2 System Software

The system software consists of macros and procedures.

##### 8.2.2.2.1 Macros and Procedures

For the purpose of estimating the conversion effort, macros and procedures are treated like complex assembler code. With 27,700 lines of macro code and procedures, 277.0 staff months are required for this part of the conversion.

### 8.2.3 Interface/Cable Fabrication

Fabrication includes manufacturing of interfaces and cables, exclusive of the cost of the materials. Approximately 11 staff months are required. Interface manufacturing includes final detail engineering drawings for circuitry necessary to interface the computer to the telemetry equipment. While standard 16-bit parallel I/O will be used, the signal and control lines may require voltage conversion and control lines may require some changes. RS 232-C interfaces should require little or no fabrication, but be used directly as supplied by Norden. Cable fabrication will require final engineering drawings and manufacturing of the cables according to applicable military standards.

### 8.2.4 System Integration

Integration activities include set-up and test of computer hardware, the set up and test of TCS and ETIS interfaces, the installation and test of all software, and functional end-to-end testing of the SCCE. The testing is primarily oriented to the verification of the software conversion and the verification that all hardware interfaces work properly. Approximately 28 staff months are required to accomplish system integration,

This integration and testing is intended to demonstrate that the converted software has been successfully integrated, that is, it all works together and implements nominal functional requirements that the hardware interfaces are working satisfactorily, and, that the rehosted system satisfies all of its functional and performance specification. The verification of SCCE functional and performance specifications is an essential part of system integration and subsequent acceptance testing. However, CSC does not have sufficient information to adequately estimate the cost of this verification. Consequently, in the estimates presented herein, CSC has limited its estimates to the integration and testing required to verify the software and interface conversion. There is a more detailed level of testing not included in these estimates. The more detailed testing would demonstrate the verification of the SCCE's operation over its entire performance envelope, and would include all possible combinations and sequences of software/hardware events and activities, such as:

(a) Verification that all possible commands and command sequences are generated and transmitted without error, under normal and peak activity conditions.

(b) Verification that all possible values of telemetry data can be properly processed.

(c) The correctness of MBA calculations.

(d) The correctness of Jammer Location calculations.

8.2.5 Acceptance Testing

Acceptance testing will demonstrate to the government that the software has been fully converted, and that the hardware interfaces from computer to telemetry equipments are functioning properly. Approximately 12 staff months are required.

8.2.6 Documentation

Documentation shall consist primarily of:

- o Additional written documentation concerning module changes and listings to augment existing SCCE software documentation.
- o Additional drawings and written documentation to show "as-built" status of all modified or new interfaces and cables.
- o Acceptance test plan.
- o Final Technical Report which describes the work accomplished, changes made to software/hardware, test results, and conclusions/recommendations. It is intended to be a summary report rather than a complete compendium of all project data.

Approximately 30 staff months will be required for documentation.

8.2.7 MIL VAX I Rehosting Costs

Table 8-2 presents the costs associated with rehosting on a MIL VAX I computer system. This cost does not include equipment transportation costs nor costs for installing the system at a government selected site.

### 8.2.8 MIL VAX I Rehosting Schedule

Figure 8-1 presents a bar chart of the schedule for rehosting on a MIL VAX I. Total calendar time required is 24 months.

## 8.3 Rehosting to DEC VAX-11/780

Once rehosting to a MIL VAX I has been performed, software conversion to DEC VAX-11/780 is not necessary since the MIL VAX I (a DEC type computer) uses DEC VAX/VMS operating system and support software. Only activities unique to a change of computer

Table 8-2. MIL VAX I Rehosting Costs

| Activity | Staff Months | Costs ($K) | |
|---|---|---|---|
| | | With A.E.R | No A.E.R |
| System Engineering | 25 | 200 | 260 |
| Software Conversion | 367.1/ 631.2** | 5050 | 2936 |
| Interfaces/Cables (labor only) | 11 | 88 | 88 |
| System Integration (partial) | 28 | 224 | 200 |
| Acceptance Testing | 12 | 96 | 86 |
| Documentation* | 30 | 240 | 200 |
| MIL VAX I Computer Hardware/Software | | 833 | 833 |
| TOTAL | 473.1/ 737.2** | $6729 | $4543 |

*Individual computer program component documentation is included in the software conversion estimate.

**Excluding/including Auxiliary Executive Routines

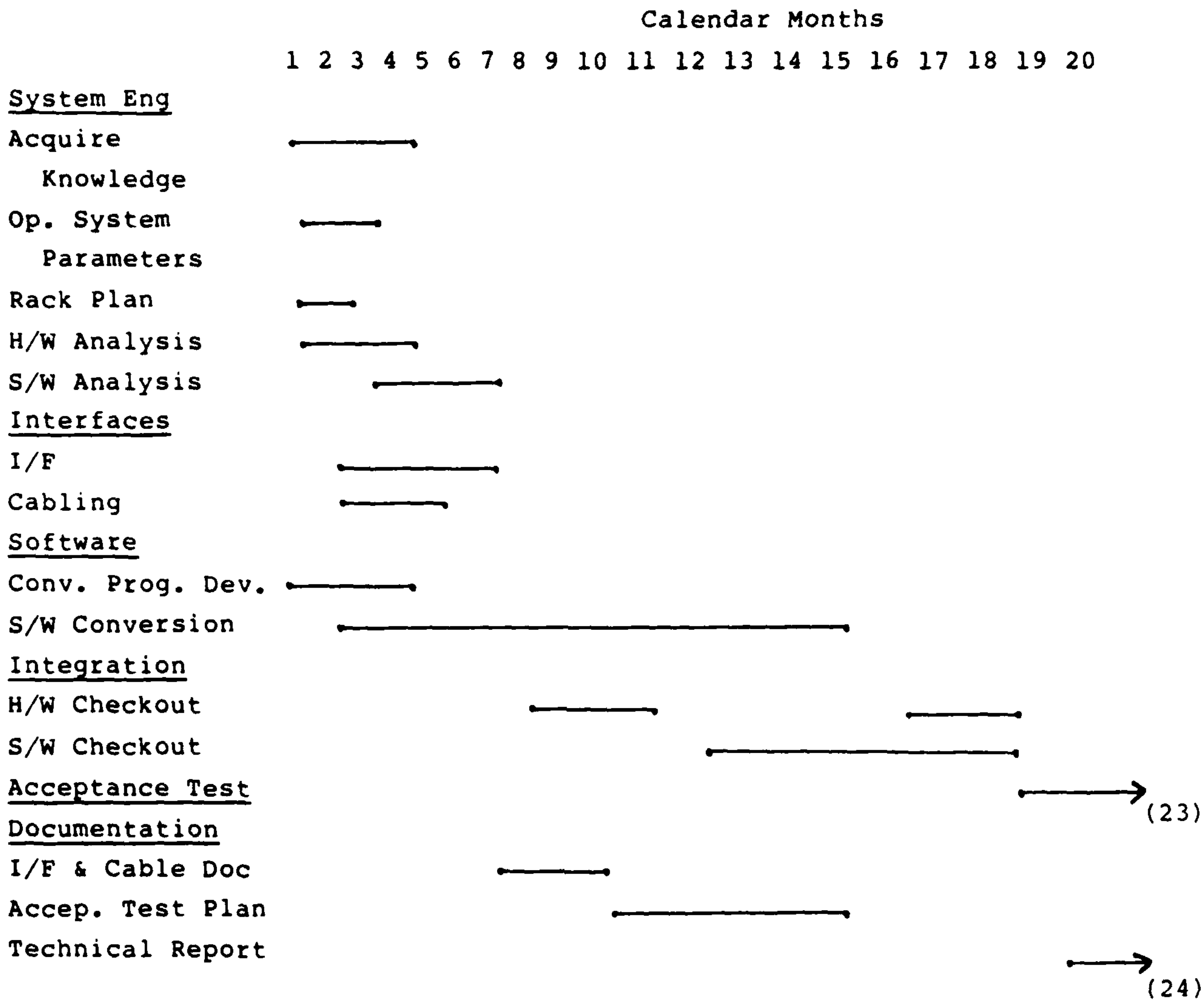



Figure 8-1. MIL VAX Rehosting Schedule

(militarized to commercial), and other interface and terminal hardware, and retesting to ensure full software/hardware integration are necessary. This section describes only those additional activities and excludes extensive system tests and government site delivery, installation, and testing.

### 8.3.1 System Engineering

System engineering includes determination of VAX/VMS operating system parameters for the DEC VAX-11/780 hardware configuration, and equipment rack/elevation/cabling and interface design.

Approximately 16 staff months are required for these activities.

### 8.3.2 Software Conversion

Little application software conversion is required. Minor tuning may be required. (A 2-satellite configuration duplicates software from a 1-satellite system with minor changes in file names, array names, etc.) Some system software must be rewritten, e.g., procedures for a two-satellite operation.

The inclusion of additional real time functions, e.g., improved JLE software, may have an adverse impact on average and peak utilization of the processor and I/O devices. Further analysis of the impact of specific proposed enhancements is recommended. Approximately 17 staff months are required for software tuning activities.

### 8.3.3 Interface/Cable Fabrication

Fabrication consists of manufacturing of interfaces and cables. Approximately 11 staff months are required for fabrication activities.

8.3.3.1 Interfaces and Cable

Interface implementation includes final detail engineering drawings, and development of circuitry necessary to interface the computer to the telemetry equipment. While standard 16-bit parallel I/O will be used, the signal and control lines may require voltage conversion, and control lines may require some changes. RS 232-C interfaces should require little or no modification to equipment as supplied by DEC and other equipment vendors.

8.3.4 System Integration

Integration activities include the set-up and test of computer hardware, the set-up and test of TCS and EITS equipment, the installation and test of all software, and functional end-to-end testing of the SCCE. The testing is primarily oriented toward operational verification of the software to ensure that it has been properly converted for the DEC VAX, and to verify that all hardware interfaces work properly. Testing does not include test of the complete SCCE performance envelope.

Approximately 18 staff months are required to accomplish system integration.

8.3.5 Acceptance Tests

Acceptance testing will be according to a test plan developed to demonstrate to the government that the software has been fully converted, that the hardware interfaces from computer to telemetry equipment are functioning properly and that the software/hardware is ready for complete performance envelope testing in the fixed DSCSOC environment. Approximately 8 staff months are allowed for acceptance tests.

8.3.6 Documentation

Documentation shall consist primarily of:

- o Additional written documentation concerning module changes (if any are specifically required for the DEC VAX) and listings to augment existing SCCE software documentation.
- o Additional drawings and written documentation to show "as-built" status of all modified or new interfaces and cables for the DEC VAX.
- o Acceptance test plan.
- o Final Technical Report which describes the work accomplished, changes mode to software/hardware, test results, and conclusions/recommendations. It is intended to be a summary report rather than a complete compendium of all data.

Approximately 22 staff months will be required for documentation.

8.3.7 DEC VAX-11/780 Rehosting Costs

Table 8-3 presents the costs associated with rehosting on a DEC VAX-11/780 computer system. This cost does not include equipment transportation costs nor costs for installing the system at a government selected site.

8.3.8 DEC VAX-11/780 Rehosting Schedule

Figure 8-2 presents a bar chart of the schedule for rehosting on a DEC VAX-11/780. Total calendar time required is 15 months.

Table 8-3. DEC VAX-11/780 Rehosting Costs

| Activity | Staff Months | Costs ($K) |
|---|---|---|
| System Engineering | 16 | 128 |
| Software Tuning | 17 | 136 |
| Interfaces/Cables (labor only) | 11 | 88 |
| System Integration (partial) | 18 | 144 |
| Acceptance Testing | 8 | 64 |
| Documentation | 22 | 176 |
| DEC VAX-11/780 Computer Hardware/Software | | $381 |
| Total | 92 | $1,117 |

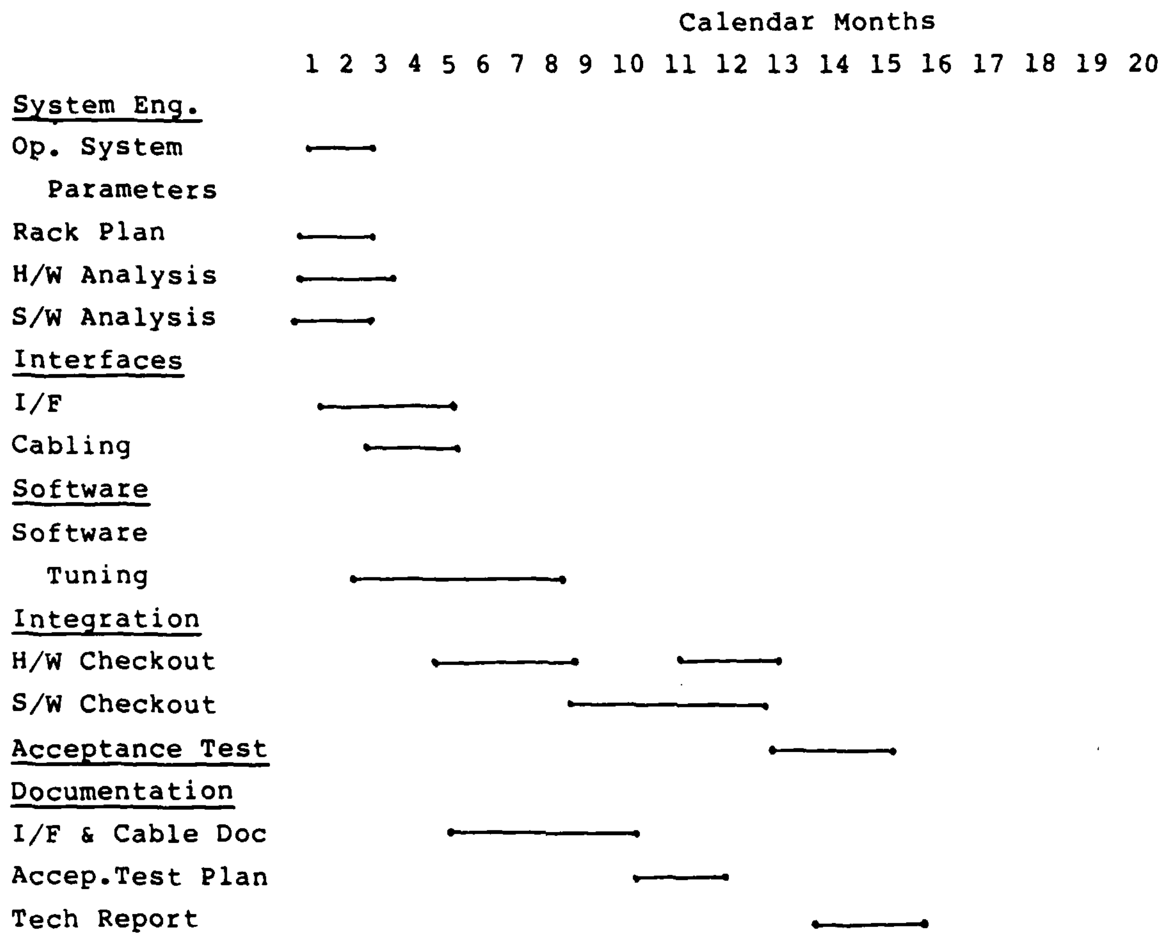



Figure 8-2. DEC VAX 11/780 Rehosting Schedule

# 9.0 CONCLUSIONS AND RECOMMENDATIONS

## 9.1 MIL VAX Based System in the SDCS

### 9.1.1 Hardware

The functionality of the SCCE to support a single active DSCS satellite can be achieved by a Norden Systems MIL VAX I based system with 4MB of primary memory. Additional militarized equipment, e.g., Miltope disks, etc., is available to complete the configuration.

### 9.1.2 Application Software

The applications software consists of 243K lines of FORTRAN and 36K lines of assembler. 90% of the FORTRAN is easily converted to the MIL VAX based system. 10% of the FORTRAN is related to computer specifics, e.g, word size, operating system interfaces, in-line Assembler, compiler unique features, and require a more complex, manual conversion. 100% of the assembler routines will require rewriting.

### 9.1.3 System Software

System software consists of 28K lines of procedures and macros. All of this will have to be rewritten.

### 9.1.4 Performance

The performance of the MIL VAX I is superior to the MODCOMP CLASSIC II/75 computer. Slightly higher processing speed, a full 32-bit machine and a more sophisticated operating system insure that a MIL VAX system will outperform the MODCOMP system.

CSC has estimated the SDCS/SCCE performance of a MIL VAX I based system, supporting one satellite, to be as shown in Table 9-1.

Table 9-1. MIL VAX System Performance (One Satellite)

| COMPUTER | PROCESSOR UTILIZATION | | | I/O UTILIZATION | | |
|---|---|---|---|---|---|---|
| | AVG | PLBK | BSY MIN | CHANNEL** | DISK* | PRTR** |
| MODCOMP | .25 | .48 | .33 | N/C | .11/.44 | .10 |
| MIL VAX I | .20 | .38 | .27 | .11 | .12/.48 | .10 |

N/C = not computed

* Average/Peak

**Average

### 9.1.5 Conversion Costs

CSC has estimated the conversion costs as shown in Table 9-2

Table 9-2. MIL VAX I Conversion Costs*
(Fully Loaded)

| COST ELEMENT | COST |
|---|---|
| LABOR | $3,785,000 |
| HARDWARE (Single Site) | 833,363 |
| TOTAL COST | $4,618,363 |

*Excludes Auxiliary Executive Routines

### 9.1.6 Added Functionality

The inclusion of some additional non-real time functions, e.g., autonomous orbit determination, can be supported by the proposed design with minimal impact on system performance. Adequate primary memory and disk storage is available to support these functions. The inclusion of additional real time functions, e.g., anomaly detection/correction may adversely impact average and peak utilization of the processor and I/O devices. Further analysis of the impact of specific proposed additions is recommended.

### 9.1.7 Potentially Difficult Areas

The potentially difficult aspects of the rehosting effort are:

a. Assembler language programming, especially bit-manipulation routines.

b. Reprogramming of FORTRAN routines with in-line assembler (on the MODCOMP).

c. Auxiliary Executive Routine programming (if required).

d. Programming of system macros.

e. Computer unique features such as:

- Operating system interfaces
- Efficiency of compiler generated code
- Compatibility of system codes and addresses with the applications software
- Real-time interfaces with TCS hardware

## 9.2 DEC VAX Based System in the DSCSOC

### 9.2.1 Hardware

Assuming that a MIL VAX SCCE has been developed, including the conversion of all SCCE software, then a DEC VAX 11/780 based system is a feasible replacement for the MODCOMP CLASSIC II/75 system. The proposed VAX 11/780 system with 6MB of memory would support 2 active DSCS satellites.

All necessary hardware is available to implement the SCCE functions.

### 9.2.2 Application Software

The applications software, consisting of 243K lines of FORTRAN and 36K lines of assembler will be directly transferrable from the MIL VAX system, without conversion. The support of two satellites requires duplicate copies of source code and respective load modules. These duplicates require disk and primary memory space, but do not significantly increase the software complexity or the software conversion effort.

### 9.2.3 System Software

System software, consisting of 28K lines of procedures and macros may require some rewriting.

### 9.2.4 Performance

The performance of the DEC VAX 11/780 is superior to the MODCOMP Classic II/75 computer. Slightly higher processing speed, a full 32-bit machine and a more sophisticated operating system insure that a VAX 11/780 system will outperform the MODCOMP system.

CSC has estimated the performance of the DEC VAX 11/780 system supporting two satellites as shown in Table 9-3.

The level of disk utilization under peak conditions may not provide sufficient performance margins. Potential work-arounds include software redesign and the use of file management to spread the load over two disks (reducing peak disk utilization to less than 50%), as well as possible hardware related methods.

Table 9-3. DEC VAX 11/780 System Performance (Two Satellites)

| COMPUTER | PROCESSOR UTILIZATION | | | I/O UTILIZATION | | |
|---|---|---|---|---|---|---|
| | AVG | PLBK | BSY MIN | CHANNEL** | DISK* | PRTR** |
| MODCOMP | .50 | .72 | .66 | N/C | .22/.55 | .30 |
| DEC VAX 11/780 | .38 | .54 | .50 | .20 | .24/.60 | .30 |

N/C = Not comp  .d

*Average/Peak

**Average

9.2.5 Conversion Costs

CSC has estimated the conversion costs as shown in Table 9-4.

Table 9-4. DEC VAX 11/780 Conversion Costs*
(Fully Loaded)

| COST ELEMENT | COST |
|---|---|
| LABOR | $ 736,000 |
| HARDWARE (Single Site) | 380,829 |
| TOTAL COST | $1,116,829 |

*Assumes software already converted for MIL VAX I

### 9.2.6 Impact of Additional System Enhancements

The inclusion of additional non-real time functions, e.g., automonous orbit determination, anomaly detection/correction may have a noticeable impact on system performance. Specifically, these additional functions may drive processor utilization above the 80% range, resulting in slower responses to operator initiated functions, slower terminal response, etc. Critical real time functions would continue to perform adequately.

### 9.2.7 Rehosting From MIL VAX to DEC VAX

Because the MIL VAX and DEC VAX computers both use the VAX/VMS operating system, no major conversion is expected in rehosting the software from a MIL VAX I system to a DEC VAX 11/780 system. However, differences in hardware between the MIL VAX and DEC VAX systems will require additional effort in the real-time interfaces with the TCS.

## 9.3 Validation of Analysis

In any analytical effort of the type reported on herein, there is some margin for error. CSC has made assumptions based on its experience and engineering judgment. CSC has attempted to assess the impact of these assumptions (refer to Appendix I, Table I-2). CSC recommends that this analysis be validated by determining the performance of the GE MODCOMP based system under peak conditions. This process would concentrate on measuring processor utilization, I/O channel utilization, disk utilization, etc., under a two satellite load, with one satellite in 4 Kbps playback condition (or other peak condition). Peak activity levels are most important although average levels are of interest too.

This validation would provide important insights into the potential risks associated with the proposed rehosting(s). CSC believes that such validation can be accomplished by GE without excessive cost or impact on other SCCE production.

## 9.4 Recommendations

As a means of reducing the programmatic risk associated with the rehosting of the SCCE, CSC makes the following recommendations:

a. The existing MODCOMP system at GE should be used as much as possible as a test bed. It can be used to verify system performance under peak loading conditions, particularly to evalate system margins.

b. The embedded assembler code on the MODCOMP should be replaced with externally called routines. This will permit the evaluation of its impact on performance.

c. Disk activity under peak loads should be measured using the MODCOMP system. If sufficient margins are not present, work-around approaches should be evaluated.

## 9.5 Growth Potential With Improved Hardware

The analysis reported on herein by CSC has examined the feasibility of rehosting the SCCE without significant increases in the SCCE processing requirements, using currently available hardware. It seems likely that over the next several years, it will be desirable to incorporate substantial enhancements into the SCCE. To assure sufficient growth capability in the rehosted system, larger performance margins with the present processing load are desirable. This can be achieved by incorporating faster processors and other higher performance hardware. For example, the NORDEN MIL VAX II outperforms the NORDEN MIL VAX I, at a lower price. Obviously, the higher performance MIL VAX II will provide higher performance margins than those reported here, and should be preferred for use in the SDCS. A potential alternative to the NORDEN computers are the VAX/VMS compatible computers built by Rugged Digital Systems, Inc., which provide comparable performance at a lower price, but with a reduced environmental envelope.

The Digital Equipment Corporation makes several higher performance VAX/VMS compatible machines in addition to the VAX 11/780 considered here. Among these, the VAX 8600 has approximately four times the processor speed of the VAX 11/780, providing a large potential for growth. The MODCOMP Corporation's Classic 32/85 is a 32-bit computer with over twice the processing speed of the 16-bit MODCOMP Classic II/75, and which will operate the existing software without conversion. Characteristics of these computers are summarized in Table 9-5.

CSC recommends that growth requirements for the SCCE be identified more specifically, in order to better assess the need for higher performance hardware.

Table 9-5. Computer Comparison

| FEATURE | CO | | | | |
|---|---|---|---|---|---|
| MANUFACTURER | MODCOMP | | DEC | | |
| MODEL | CLASSIC II/75 | CLASSIC 32/85 | VAX 11/780 | VAX 11/785 | VA |
| WORD SIZE | 16 | 32 | 32 | 32 | |
| MIPS | .96 | 2.4 | 1.06 | 1.5 | |
| PRIMARY MEMORY (MB) | 2 | 2 - 64 | 2 - 64 | 2 - 64 | 1 |
| DISK CAPACITY (MB)* | 67 | 67 | 121 | 121 | |
| DISK AAT (MS) | 30 | 30 | 30 | 30 | |
| DISK TRANSFER RATE (MB/S) | 1.2 | 1.2 | 1.2 | 1.2 | |
| TAPE SPEED (IPS) | 75 | 75 | 125 | 125 | |
| OPERATING SYSTEM | MAX IV | MAX IV | VAX/VMS | VAX/VMS | V |
| OP. TEMP. RANGE (OC) | 0 - 40 | 0 - 40 | 10 - 40 | 10 - 40 | 1 |
| SHOCK (g/MS) | 3/11 | 3/11 | 3/11 | 3/11 | 3 |
| PRICE (MINIMUM CONFIG) | $ 50K | $150K | $145K | $195K | $ |
| PRICE (TYPICAL SYSTEM) | $115K | $248K | $396K | $442K | $ |

* LARGER DISKS AVAILABLE FOR ALL COMPUTERS

Table 9-5. Computer Comparison

| COMPUTER | | | | | | | |
|---|---|---|---|---|---|---|---|
| | DEC | | | NORDEN | | RUGGED | DIG. SYS. |
| SSIC 32/85 | VAX 11/780 | VAX 11/785 | VAX 8600 | MIL VAX I | MIL VAX II | R/780 | R/785 |
| 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| 2.4 | 1.06 | 1.5 | 4.45 | 1.0 | 1.4 | 1.06 | 1.5 |
| 2 - 64 | 2 - 64 | 2 - 64 | 12 - 82 | 2 - 4 | 2 - 8 | 2 - 16 | 1 - 16 |
| 67 | 121 | 121 | 456 | 134 | 134 | 456 | 456 |
| 30 | 30 | 30 | 36 | 26 | 26 | 36 | 36 |
| 1.2 | 1.2 | 1.2 | 1.28 | 1.28 | 2.2 | 2.2 | 2.2 |
| 75 | 125 | 125 | 125 | 75 | 75 | | |
| MAX IV | VAX/VMS | VAX/VMS | VAX/VMS | VAX/VMS | VAX/VMS | VAX/VMS | VAX/VMS |
| 0 - 40 | 10 - 40 | 10 - 40 | 10 - 40 | -54 - 55 | -54 - 40 | 0 - 50 | 0 - 50 |
| 3/11 | 3/11 | 3/11 | 3/11 | 15/11 | 15/11 | 15/11 | 15/11 |
| $150K | $145K | $195K | $500K | | | $390K | $500K |
| $248K | $396K | $442K | $806K | $730K | $590K | | |

2

## APPENDIX I

## SOFTWARE ANALYSIS METHODOLOGY

### 1.0 SOFTWARE ANALYSIS

The primary objective of the SCCE software analysis is to determine hardware requirements for rehosting the system. This primary objective is composed of the four secondary objectives which follow.

### 1.1 Establishing Hardware Processing Requirements

Hardware processing requirements are a function of the number of executable machine instructions invoked at peak loading and the processing speed of the central processor. Therefore, one objective of the software analysis is to determine the number of executable FORTRAN and assembler instructions contained in the system.

### 1.2 Input/Output Requirements

Input/output performance is measured by the utilization of specific I/O devices, e.g., disk, tape, CRT; and by the utilization of I/O channel capacity. Each I/O device is characterized by an average access rate. I/O channels are characterized by a maximum data transfer rate. The software has been analyzed to evaluate the I/O traffic.

### 1.3 Establishing Primary Storage Requirements

Primary storage segments have been established by using tabulations of load module storage taken from the Computer Program Performance Specifications.

### 1.4 Establishing Disk Storage Requirements

Disk storage requirements have been established by using files descriptions provided in Computer Program Performance Specifications.

## 2.0 APPROACH

The CSC approach to utilization and sizing includes categorization of the SCCE software, analysis methodology, and modeling techniques. Each of these components of the CSC approach are detailed in the following paragraphs.

### 2.1 Software Categorization

The SCCE software is divided into two basic categories: system software and application software (Fig I-1)

#### 2.1.1 System Software

The system software consists of machine dependent macros and procedures. CSC has assumed that all system software must be rewritten for a new computer, and has further assumed that the rewriting effort will be the same irrespective of the host computer. Therefore the conversion effort for system software has been based on a lines-of-code count.

#### 2.1.2 Application Software

The SCCE applications software consists of two Computer Program Configuration Items (CPCIs): Telemetry and Command Program (TCP) and Communications Configuration Program (CCP). Also included in the applications software are the utilities and common data variables necessary to support each CPCI, and auxiliary executive functions.

The SCCE functions are divided into:

a. Real time functions

b. Regularly scheduled functions

c. Support functions

d. Utilities

e. Auxiliary Executive Routines

SYSTEM SOFTWARE

MACROS
PROCEDURES

APPLICATIONS SOFTWARE

o REAL TIME

- TELEMETRY ACQUISITION
- TELEMETRY PROCESSING
- COMMAND SEQUENCE GENERATION
- COMMAND MANAGEMENT
- DISPLAY PROCESSING
- INTERSITE DATA TRANSFER

o REGULARLY SCHEDULED

- ACTIVITY REPORT GENERATION
- SUBSYSTEM ANALYSIS
- ACTIVE/RELOAD

o SUPPORT/BATCH

- COMMUNICATIONS CONFIGURATION MANAGEMENT
- DATA BASE GENERATION
- HARDWARE DIAGNOSIS

o UTILITIES

- BIT MANIPULATION
- COMMAND FORMATTING
- DATA BUFFERING, PACKING, UNPACKING

o AUXILIARY EXECUTIVE FUNCTIONS

- TERMINAL DEVICE INTERFACE
- DATA TRANSFER
- FILE MANAGEMENT
- PRINTER SPOOLING

Figure I-1. SCCE Software

Many of the real time and regularly scheduled functions can be initiated at any time by a request from the operator.

The real time (R/T) functions consist of Telemetry Acquisition, R/T satellite performance evaluation provided by the telemetry processing, and MBA Configuration Verification functions, R/T Command Generation and Transmission, Jammer Detection, and R/T Display Generation. These functions are performed by core-resident and interactive modules which execute in the computer memory concurrently. Among the R/T functions, Telemetry Acquisition has the highest priority with Command Management the next highest. R/T Display Generation has the lowest priority.

The regularly scheduled functions consist of Subsystem Analysis, Activity Report Generation, and Archival/Reload. These functions are all regularly scheduled on data span termination (i.e., approximately every two hours). They share the computer memory and resources with the R/T functions. Therefore, since their priorities are lower, they execute when the R/T functions are awaiting external input requests. Among the regularly scheduled functions, Archival has the highest priority and Activity Report Generation the lowest.

The software system executes under the control of the SCCE operators and controllers. The operating system and the auxiliary executive functions provide executive and input/output routines for the applications software modules. Executive routines include task scheduling and dispatching on a priority basis, interrupt handling, and memory and device allocations. Input/output routines include communications with the CRTs and keyboards, data transfers to and from the SCCE ground station hardware, file management services, and printed outputs.

### 2.1.3 Computer Languages

The SCCE software is written in FORTRAN, MODCOMP assembler, and a combination of both languages (e.g., "in line assembler").

CSC has analyzed software to determine how many CPCs and utilities are written exclusively in FORTRAN, how many are written exclusively in assembler, and how many make use of in-line assembler. Those CPCs and utilities written in, or making use of, assembler must be rewritten during the conversion process. Table I-1 presents the results of this part of the software analysis.

Table I-1
Application Software - Lines of Code
by Functional Category

| CATEGORY | FORTRAN LINES | ASSEMBLER LINES |
|---|---|---|
| 1. Telemetry Acquisition & Processing | 9,974 | 21 |
| 2. Command Generation & Transmission | 14,146 | 548 |
| 3. Payload Analysis | 29,415 | 0 |
| 4. Data Span Processing | 5,607 | 0 |
| 5. Display Generation | 9,869 | 0 |
| 6. Intersite Data Transfer | 2,656 | 0 |
| 7. Operating System Interface | 3,750 | 119 |
| 8. Data Span Report Generation | 3,191 | 0 |
| 9. Support Systems | 8,211 | 0 |
| Utilities | 17,383 | 3,888 |
| TOTAL (Executable, without comments) | 104,202 | 4,576 |
| COMMENTS (110% of total) | 115,780 | 5,084 |
| Unexecutable (5% of total) | 11,578 | 508 |
| TOTAL (without COMMON) | 231,560 | 10,168 |
| COMMON | 11,023 | 0 |
| Auxiliary Executive Routines | 0 | 26,406 |
| TOTAL | 242,583 | 36,574 |

## 2.2 Software Analysis Methods

### 2.2.1 Software Hierarchy

The application software consists of modules called computer program components (CPCs), and utility routines. The CPCs are grouped functionally into executable "load modules". These load modules are the tasks managed by the operating system. CSC has focused its analysis of processor performance on these load modules, and their usage of utility routines. In addition, the software is grouped into two major computer Program Configuration Items (CPCIs). These are the Telemetry and Command Program (TCP) and the Communications Configuration Program (CCP). The software hierarchy is illustrated in Figure I-2.

### 2.2.2 Processor Utilization Methodology

The analysis of processor utilization (and I/O device utilization) depends on the number of machine instructions to be executed for each function and the frequency of execution of the function. CSC has determined the number of machine instructions per function (load module) by a detailed "path" analysis of source code listings. (This process takes into account the number of iterations through loops.) In addition, the number of (executable) lines of code were counted as well as the number of comments.

For high priority load modules (e.g., real time functions) the path analysis was used to produce the instruction count. However, for lower priority load modules, the lines-of-code, suitably scaled, was used as the basis for instruction count. The frequency of invocation of load modules was determined by reading and interpreting information contained in appropriate Computer Program Product Specifications.

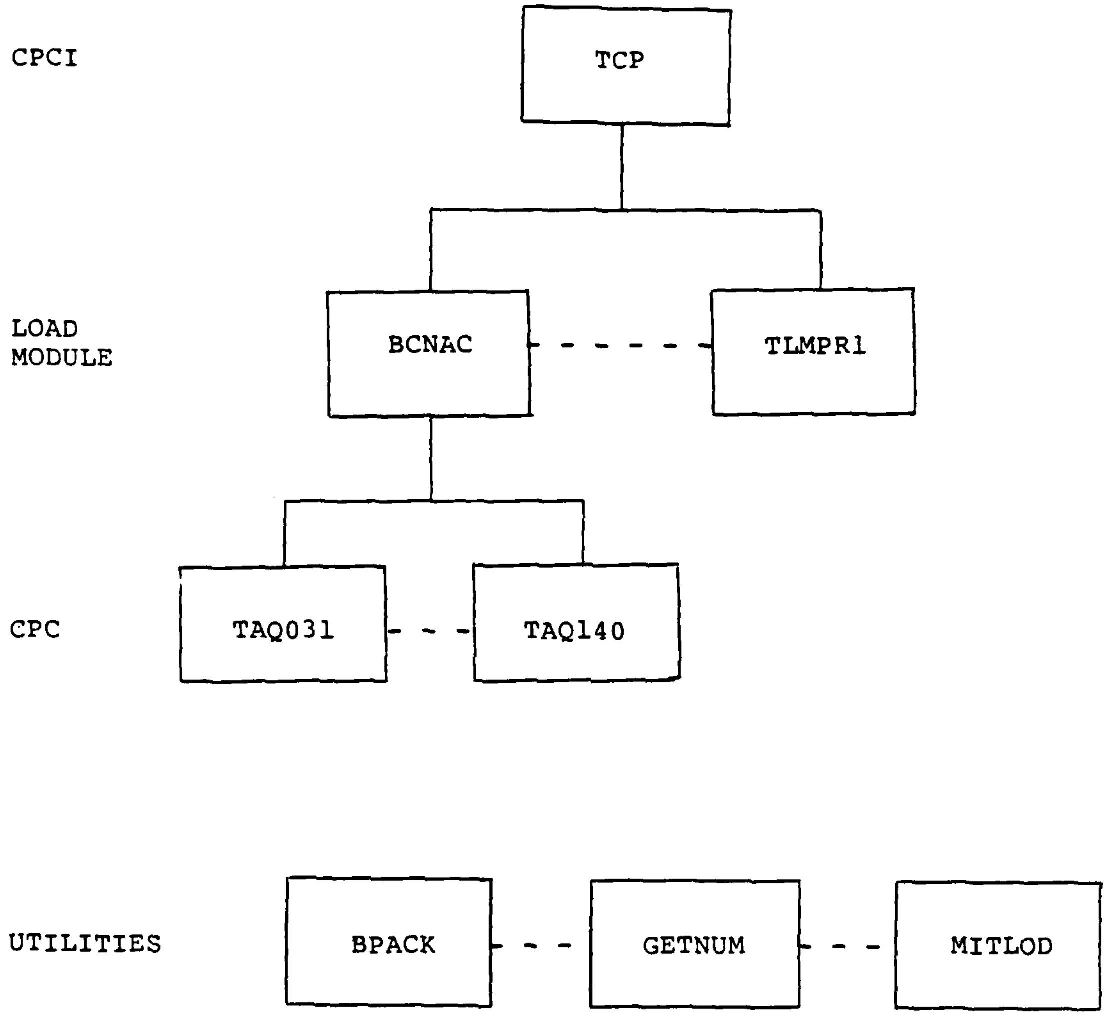



Figure I-2. Hierarchy of SCCE Application Software

The processor loading has been calculated as follows:

High priority load modules:

$$PL = \sum_{i=1}^{n} Ci \quad (fi) \ (NoIi)$$

where

PL = processor loading (instr/sec)

fi = frequency of invocation of i th load module

NoIi= number of high level language instructions to implement load module "i"

n = total number of load modules

$$Ci = \frac{\text{machine instructions}}{\text{high level language instructions}}$$

$$NoIi = \sum_{j=1}^{mi} Pij \ (NoIij)$$

where

mi = number of paths through ith load module

NoIij = number of instructions on jth path through ith load module

Pij = probability of invoking j th path through i th load module

Other load modules

$$PL = \sum_{i=1}^{n} Ci \quad (fi) \quad (LoCi) \quad (Ki)$$

where

$L_oC_i$ = Lines of code to implement i th load module.

$$K_i = \frac{\text{High Level Language Instructions}}{\text{Lines of Code}} \text{ for i th load module}$$

Ki is based on the function of load module i, and a statistical analysis of load modules for which both lines of code and number of instructions were determined.

Two values of Ki are used: a value of 4 is used for I/O and data manipulation intensive routines; a value of 100 has been used for mathematical processing intensive routines (e.g., CCP).

Two values of Ci are used: a value of 4 is used for FORTRAN instructions; a value of 1.2 is used for assembler instructions.

To determine processor utilization the following approach has been taken.

$$\text{UTIL} = \frac{\text{PL x (1+OH)}}{\text{MIPS}}$$

where

PL = Processor Loading (described above) (instr/sec)

MIPS= Processor instruction rate (instr/sec)

OH = Overhead associated with operating system (0 OH 1)

= .25 in CSC's analysis

2.2.3 I/O Analysis

I/O analysis has included I/O channel peak instantaneous utilization, peak average channel utilization, and device utilization. I/O channel utilization has been calculated by assuming that all devices on the channel are operating at maximum rate, and assuring that under this worst-case condition the channel was not

overloaded. Peak average channel utilization takes into account the fact that the applications software drives the various devices on the data bus at a duty cycle which is considerably lower than 100%. This, in turn, reduces total activity on the data bus. The principal load on the bus is the disks. Assuming that the files for two active satellites are on a single disk and we have a device utilization of $U_D$, then maximum data transfer will be generated when disk head seeks are not required, and a full track of data is accessed in one rotational period of the disk. This data is then transmitted on the UNIBUS at the disk transfer rate. The channel utilization, $U_C$ is given by the following:

$$U_C = \frac{\frac{L}{T}}{R_T} \times U_D$$

where

$R_T$ = Disk transfer rate (KW/S)

T = Disk rotational period (sec)

L = Record length (Kwords)

$U_D$ = Disk utilization

Device utilization has been analyzed as follows:

For disk utilization, CSC has determined that maximum disk traffic is generated by the real-time programs, primarily in support of telemetry acquisition and telemetry processing. Disk activity has been calculated in the following manner:

$$\text{ACTIVITY} = \sum_{i=1}^{n} fi \sum_{j=1}^{mi} (Pij)\ (Nij)$$

where

ACTIVITY is measured in accesses/sec

fi = frequency of invokation of ith load module

pij = probability of jth path through ith load module

Nij = number of device accesses for jth path through ith load module

n = number of load modules

m = number of paths through ith load module

The disk activity is compared with disk access capacity to establish disk utilization.

For CRT and printer/plotter devices, the traffic rate is primarily dependent on interactive scenarios in which operator actions determine device usage. CSC has constructed typical scenarios for these devices.

### 2.4 Sources of Uncertainty

In conducting this study, CSC has recognized that much of the information that forms the basis for quantitative results has uncertainties associated with it. CSC has used available SCCE documentation, but has not been able to verify its interpretation of these documents. Some parameters associated with the various computers are proprietary, e.g., the performance of the operating systems. The availability of this information has affected the models used by CSC. In this section, CSC has attempted to estimate the probable impact of these uncertainties.

#### 2.4.1 Processor Utilization Analysis

The potential uncertainty sources which impact processor utilization, and their estimated impact, appear in Table I-2.

Assuming that the various sources of uncertainty are additive, a worst case bound is -.7; +.75. That is, we can expect

that our estimates of processor utilization are highly likely to be in the range of .3U to 1.75U where U is the calculated value of processor utilization. Assuming that the uncertainties are approximately statistically independent (a weak assumption), then average error bounds would be $-.7/\sqrt{5}$; $+.75/\sqrt{5}$ (or -.3; +.33). We can expect that our estimates of processor utilization are probably in the range of .7U to 1.33U.

### 2.4.2 I/O Utilization Analysis

The potential uncertainty sources which impact I/O accesses and their estimated impact appear in Table I-3 and Table I-4.

For disk utilization, assuming that the sources of uncertainty are additive, a worst case bound on the impact of uncertainty is approximately $\pm$ 0.6. That is, we can expect that our estimates of disk utilization are highly likely to be in the range of .4 $U_D$ to 1.6 $U_D$, where $U_D$ is the calculated value of $U_D$. Assuming that the uncertainties are statistically independent, average error bound would be $\pm .6/\sqrt{4}$ (or $\pm$ .3). We can expect that our estimates of processor utilization are probably in the range of .7 $U_D$ to 1.3 $U_D$.

Average channel utilization, calculated under peak loading conditions, is dependent on the peak utilization of the channel by the disks, which are the dominant channel load. Disk utilization has the uncertainties discussed above. Also, the size of the record accessed by the disk is a random variable. CSC's analyses have used an entire track as the record size, defining an extreme worst-case situtation. In addition, CSC has assumed that the effect of very short records, which may be accessed in a disk buffer without any disk rotation, and the effect of long records requiring more than 1 access per I/O request, are negligible.

### 2.4.3 Interpretation of Uncertainty Sources

Figure I-3 shows the estimated values under peak (playback) conditions for the processor utilization and disk utilization.

Table I-2. Uncertainty Sources Impacting Processor Utilization

| UNCERTAINTY SOURCE | NOMINAL | RANGE | IMPACT |
|---|---|---|---|
| Operations System Overhead | .25 | .2-.4 | -.05;+.15 |
| Ratio of Instructions/Lines/Code | 4 | 2-10 | -.15;+.15 |
| Frequency of Execution | N/A | N/A | -.4; +.25 |
| Utility calls for utilities | N/A | N/A | -0; +.1 |
| 16-bit vs 32-bit Instruction Relative Rate | N/A | N/A | -.1; +.1 |

Table I-3. Uncertainty Sources Impacting Input/Output Utilization

| UNCERTAINTY SOURCE | DEVICE | NOMINAL | RANGE | IMPACT |
|---|---|---|---|---|
| Operating System Overhead | Disk | .2 | .1-.3 | -.1;+.1 |
| Use of average access time | Disk | 30 ms | 16-50 | -.1;+.1 |
| Frequency of execution | All | N/A | N/A | -.4;+.25 |
| Operating scenario | CRT | N/A | N/A | -.2;+.05 |
| Uncounted CPCs | All | N/A | N/A | -.0;+.2 |

Table I-4. Uncertainty Sources Impacting Channel Utilization

| UNCERTAINTY SOURCE | NOMINAL* | RANGE | IMPACT |
|---|---|---|---|
| Disk Utilization | $U_D$ | .3;+.3 | -.3;+.3 |
| Record Size Per Disk Access | L | .9;+0 | -.9;+0 |

*Refers to Appendix A, paragraph 2.2.3

These values depict the impact of the uncertainty sources on estimated values of utilization. The line graphs show the average and one standard deviation ( $\sigma$ ) and two standard deviation (worst case) ranges. The processor utilization graphs show that the MODCOMP Classic II/75 may be overloaded (115%) under these peak conditions and even at the one $\sigma$ point (94%) may be too close to its full capacity. The DEC VAX 11/780 may have processor utilization as high as 86% (too high to allow enhancements to be added). The disk utilization graphs show that the DEC VAX 11/780 may be as high as 96% (too high), and even at the one $\sigma$ point (78%) may be too high. As discussed in 7.6.3, a reconfiguration of the files can reduce the average to about 50%, with a one $\sigma$ value of 65%, and a worst case value of 80%.

Note that these ranges of values are not associated with different operational conditions. They show the potential impact of uncertainties in CSC's methodology and data. To the extent that other, unknown, sources of uncertainty (i.e., not considered here) may exist, these results could be substantially different.

## 2.5 Cases Analyzed

CSC has identified three cases of interest for performance analysis. They are:

a. An average (or baseline) condition that represents normal conditions on the SCCE processor, with either 1 or 2 active satellites.

b. A playback condition in which one satellite data stream is assumed at a 4Kbps playback rate. In the 2 satellite situation, the second satellite data stream is real time telemetry at a 1 Kbps rate.

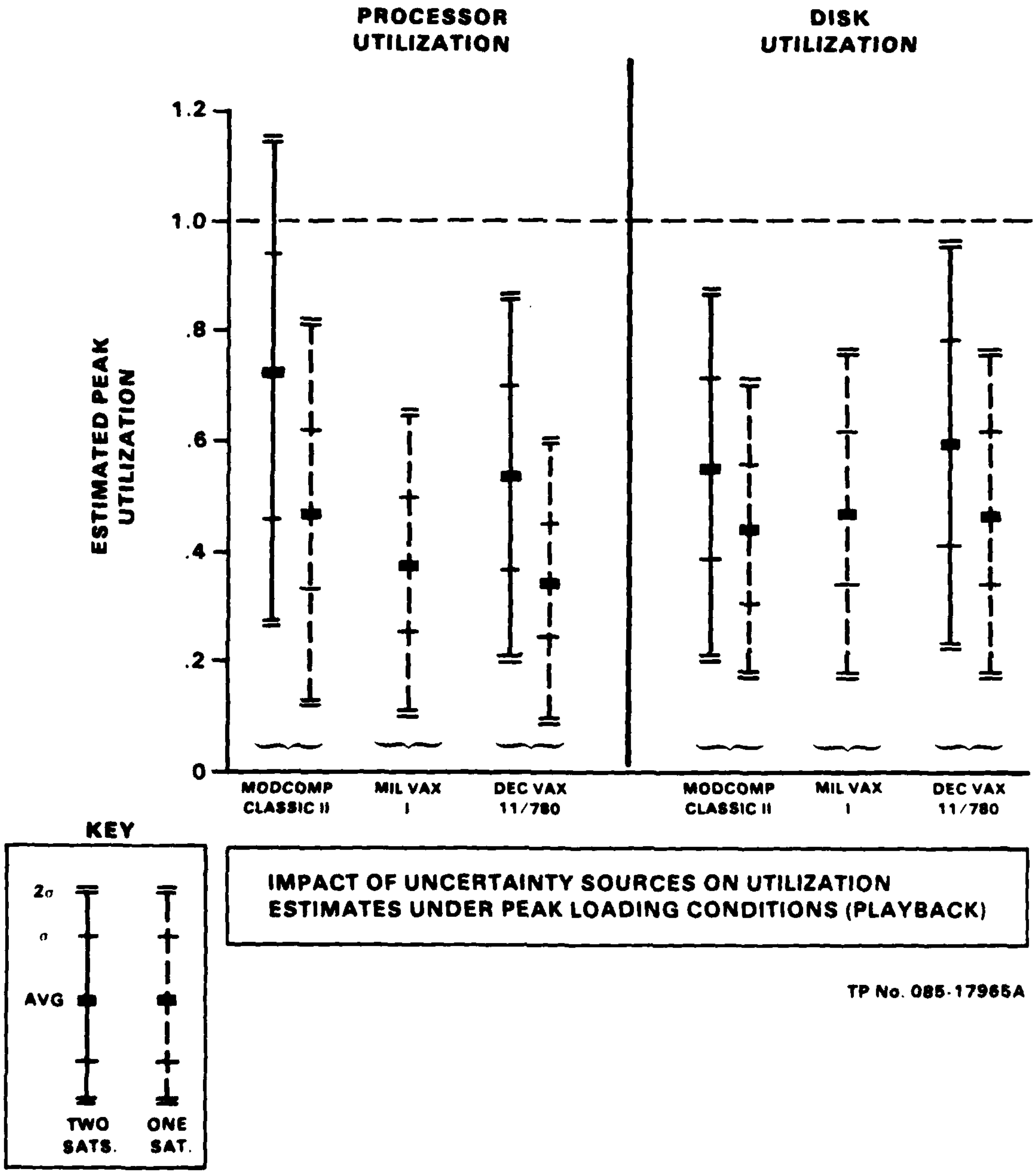



Figure I-3. Estimated Peak Utilization

c. A "busy minute" in which all the real time functions occur at their normal rate, data span analysis and wrap-up processing coincide (time-wise) with the real-time functions, and other functions are delayed until the "busy minute" is completed. The "busy minute" has been analyzed for both 1 and 2 satellites, with the respective "busy minutes" for each of the 2 satellites coinciding.

These cases have been defined by the frequency of execution assigned to each load module. In the average (or baseline) case, the frequencies of execution have been derived from analyses of G.E. prepared documentation, specifically the Computer Program Performance Specification. The playback and busy minute frequencies have been determined by appropriate modification to the baseline data. Frequency data (actually expressed as the associated period) appears in Table I-4. Also, Table I-4 indicates (X) which load modules were analyzed by instructions on a path basis.

Table I-5. Load Module Periods

| CATEGORY | FUNCTION | LOAD MODULE | PATH ANAL | PERIOD AVG | PERIOD PLYBK | PERIOD BSY MIN |
|---|---|---|---|---|---|---|
| 1 | Real Time Telemetry, Acquisition & Processing | BCNAC | X | 2 sec | 0.5 sec | 2 sec |
| | | EVREAD | X | 10 min | 10 min | 10 min |
| | | TLMAC | X | 2 sec | 0.5 sec | 2 sec |
| | | TLMCT1 | X | 10 min | 10 min | 10 min |
| | | TLMPR1 | X | 1 min | 15 sec | 1 min |
| 2 | Command Generation, Transmission, Verification | CMDCT1 | X | 10 min | 10 min | 10 min |
| | | CMDRN1 | X | 10 min | 10 min | 10 min |
| | | CMDSEG | X | 10 min | 10 min | 10 min |
| | | CMDTM1 | X | 10 min | 10 min | 10 min |
| | | CMDVF1 | X | 10 min | 10 min | 10 min |
| | | CMDXM1 | X | 10 min | 10 min | 10 min |
| 3 | Payload Analysis | CCPFUN | | 5 min | 10 min | 30 min |
| | | ORBDET | | 1 hr | 1 hr | 1 hr |
| 4 | Data Span Processing | ARCHV1 | X | 1 hr | 1 hr | 1 min |
| | | RELOAD | X | 24 hr | 24 hr | 24hr |
| | | SUBAN1 | X | 1 hr | 1 hr | 1 min |
| | | WRAP1 | X | 2 hr | 2 hr | 1 min |
| 5 | Display Generation | AFILE1 | X | 1 min | 1min | 1 min |
| | | BEACO1 | X | 1 min | 1 min | 1 min |
| | | CONFI1 | X | 30 sec | 30 sec | 30 sec |
| | | CSTAT1 | X | 15 min | 15 min | 15 min |
| | | DCATI | X | 2 min | 2 min | 2 min |
| | | DFILE1 | X | 15 min | 15 min | 15 min |
| | | DISCO1 | X | 1 min | 1 min | 1 min |
| | | DISGA1 | X | 15 sec | 15 sec | 15 sec |
| | | DISOA1 | X | 15 sec | 15 sec | 15 sec |
| | | GRAPH1 | X | 30 min | 30 min | 30 min |
| | | GRDSTI | X | 15 min | 15 min | 15 min |
| | | LIST1 | X | 12 min | 12 min | 12 min |
| | | SETS1 | X | 1 min | 1 min | 1 min |
| | | SUBD1 | X | 1 min | 1 min | 1 min |
| | | TFILE1 | X | 2 min | 2 min | 2 min |
| | | TDMA | X | 1 min | 1 min | 1 min |
| | | TPD1 | X | 1 min | 1 min | 1 min |

Table I-5. Load Module Periods (Cont'd)

| CATEGORY | FUNCTION | LOAD MODULE | PATH ANAL | PERIOD AVG | PERIOD PLYBK | PERIOD BSY MIN |
|---|---|---|---|---|---|---|
| 6 | Intersite Data Transfer | DOSLNK | | 10 min | 10 min | 2 min |
| | | IDT | | 10 min | 10 min | 10 min |
| 7 | Operating Sys Interface | HELP | | 24 hr | 24 hr | 24 hr |
| | | HWDIAG | | 1 hr | 1 hr | 1 hr |
| | | SRE | X | 6 sec | 1.5 sec | 6 sec |
| 8 | Data Span Report Generation | LIMSU1 | | 1 hr | 1 hr | 1 hr |
| | | RGCMD1 | | 1 hr | 1 hr | 1 hr |
| | | RGGEN1 | | 1 hr | 1 hr | 1 hr |
| | | RGOP1 | | 1 hr | 1 hr | 1 hr |
| | | RGQUA1 | | 1 hr | 1 hr | 1 hr |
| | | RGSTA1 | | 1 hr | 1 hr | 1 hr |
| | | RPGEN1 | | 1 hr | 1 hr | 15 min |
| 9 | Support Systems | DSORCE | | 10 min | 10 min | 10 min |
| | | FIG | | 24 hr | 24 hr | 24 hr |
| | | MIFG | | 24 hr | 24 hr | 24 hr |
| | | MITG | | 24 hr | 24 hr | 24 hr |
| | | Traing | | 8 hr | 8 hr | 8 hr |

## GLOSSARY

| | |
|---|---|
| bps | bits per second |
| CCP | Communication Configuration Program |
| CD/CPS | Control and Display/Computer and Peripheral Subsystem |
| CIV | Computer Interface Unit |
| CMI | Computer Memory Interconnect |
| CPC | Computer Program Component |
| CPCI | Computer Program Configuration Item |
| CPU | Central Processor Unit |
| CRT | Cathode Ray Tube (display terminal) |
| D/A | Digital-to-Analog |
| DEC | Digital Equipment Corporation |
| DOCS | DSCS Operations Control System |
| DOSS | DSCS Operational Support System |
| DSCSOC | DSCS Operations Center |
| ECC | Error Checking and Correcting |
| IPM | Interim Production Model |
| I/O | Input/Output |
| JLE | Jammer Location Electronics |
| Kb | Kilobit |
| KB | Kilobyte |
| MB | Megabyte |
| MBA | Multiple Beam Antenna |
| MHD | Moving Head Disk |
| MIPS | Million of Instructions Per Second |
| MIL VAX I | A class of Norden Corporation Militarized computer |
| MMI | Man-machine Interface |
| MODCOMP | Modular Computer Systems, Inc. |
| MTU | Magnetic Tape Unit |
| Norden | Norden Division of United Technologies |
| PSCCE | Production Satellite Configuration Control Element |
| R/T | Real-time; receive/transmit |
| RS-232C | Electoronic Industries Association (EIA) standard for bit serial communications hardware |

| | |
|---|---|
| SCCE | Satellite Configuration Control Element |
| SCF | Satellite Control Facility |
| SCT | Satellite Channel Transponder |
| SDCS | Survivable DSCS Control System |
| SIG.MUX. | Signal Multiplexor |
| TCG | Time Code Generator |
| TCS | Telemetry and Command Subsystem |
| TCP | Telemetry and Command Program |
| TCT | Time Code Translator |
| TPU | Telemetry Playback Unit |
| UNIBUS | Name for DEC's I/O bus |
| VAX | Class of DEC Computer |
| VMS | Name of operating system for VAX computers |

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

## REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

| | |
|---|---|
| 1. REPORT NUMBER | 2. GOVT ACCESSION NO. AD-A161 157 |
| 3. RECIPIENT'S CATALOG NUMBER | |
| 4. TITLE (and Subtitle) SCCE REHOSTING FEASIBILITY ASSESSMENT - DRAFT | 5. TYPE OF REPORT & PERIOD COVERED |
| | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s) S. Dressler, B. Kerne, W. Nakisher, P. C. Wood | 8. CONTRACT OR GRANT NUMBER(s) DCA100-8[illegible]-C-0044 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Computer Sciences Corporation, 6565 Arlington Boulevard, Falls Church, Virginia 22046 | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS Satellite Communications System Development Div., Defense Communications Engineering Center, Reston, Virginia | 12. REPORT DATE 31 October |
| | 13. NUMBER OF PAGES 142 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) | 15. SECURITY CLASS. (of this report) Unclassified |
| | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Satellite Communications System Development Division
Defense Communications Engineering Center (5 copies)

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

DSCS, SCCE, Satellite Control

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An analysis of the feasibility of rehosting the DSCS Satellite Configuration Control Element to a militarized computer for use in the Survivable DSCS Control System. Software conversion, hardware, system performance and cost are analyzed.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ATE

LMED

-8